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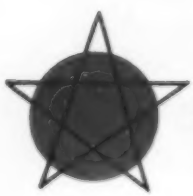

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

October 1956

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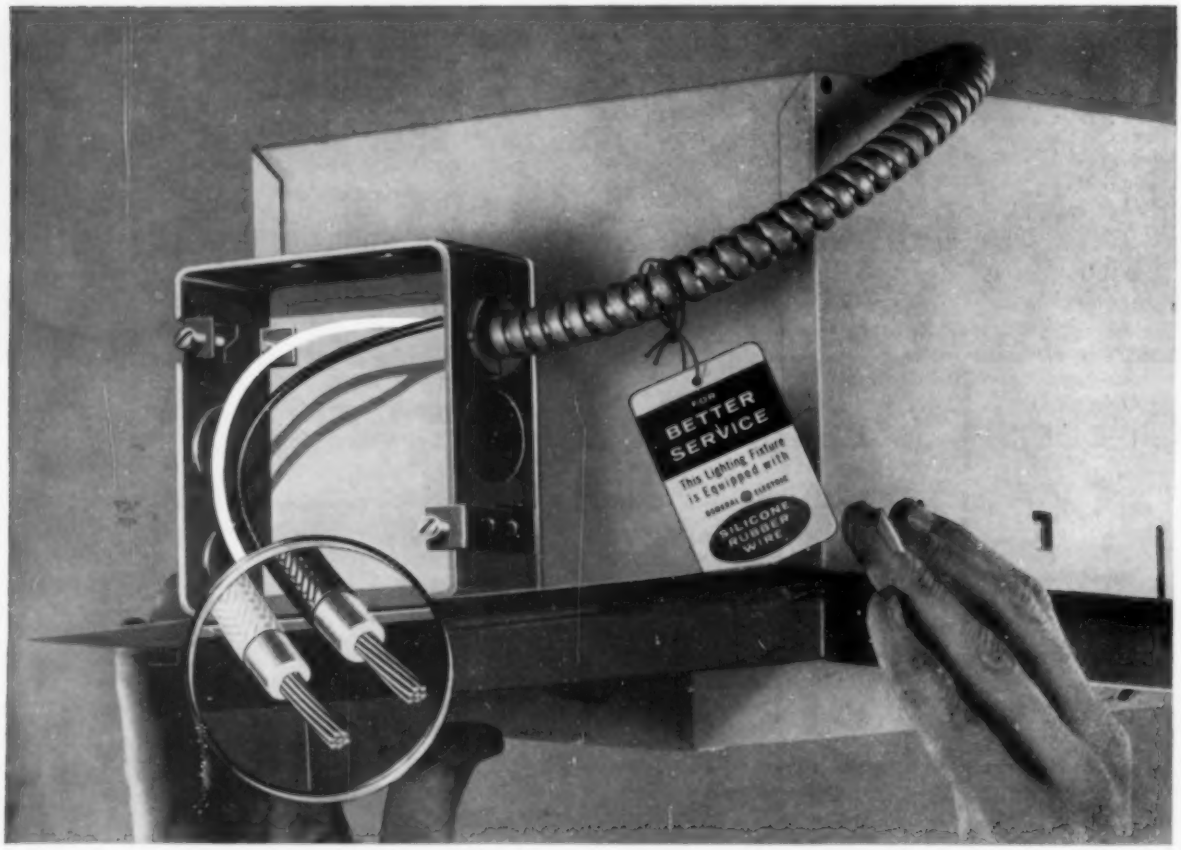

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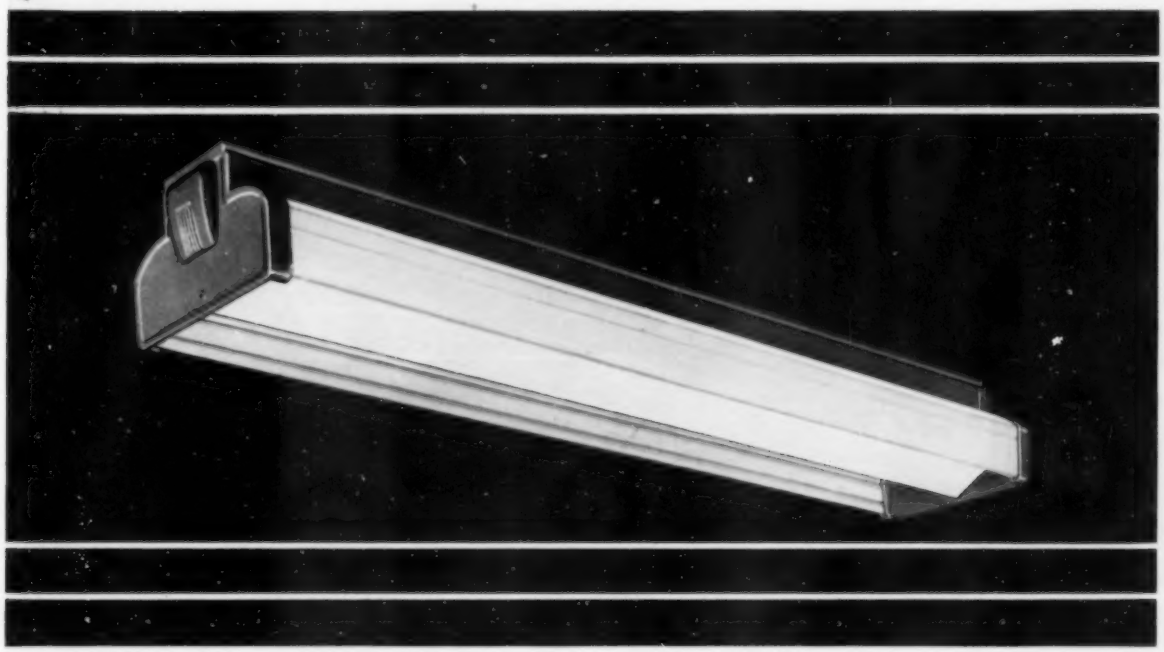

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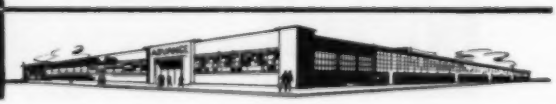

Marshall N. Waterman — President, 1956-1957

Illuminating Engineering Society

DURING the administrative year of 1956-1957, the Illuminating Engineering Society will embark on its second half-century of existence. Its continuing success seems assured. Assured, not only through its constructive new programs, but through the man elected to guide their application. In Marshall N. Waterman, the membership has chosen a man who was himself the instigator of many of the progressive plans now under way, and active in the formation of numerous others. Mr. Waterman's activity in behalf of I.E.S. has long been a factor in its progress. Indeed, on occasion his time, and talent for leadership, have been in demand from several directions at the same time! In 1953 when he was elected General Secretary, he was already Chairman of the Finance Committee, and Chairman of the New York Section, the Society's largest local group. He has served also as Chairman of the Advisory Policy Committee, and of the Committee on Lighting Study Projects in Industry, and has, of course, been a member of numerous other I.E.S. committees.

As a lecturer on many phases of illuminating engineering, Mr. Waterman has been in considerable demand. He has appeared on Regional Conference programs in every part of the U. S. and Canada, and in 1952 was invited to present a paper before the French Illuminating Enginering Society in Toulouse, France. His distinguished contributions to illuminating engineering were further recognized recently in his election as a Fellow of I.E.S. (see I.E., September 1956, page 13A).

In industry, Mr. Waterman is assistant commercial engineering manager of the Westinghouse Lamp Division, Bloomfield, N. J. Active in the lighting profession for nearly thirty years, Mr. Waterman was graduated from Massachusetts Institute of Technology in 1924 with an electrical engineering degree. In 1926 he joined the lighting sales department of the Central Hudson Gas and Electric Corp., Poughkeepsie, N. Y., and later became a supervisor of lighting sales. In 1942 he joined the War Production Board in Washington, D. C. as assistant director of the Building Materials Division. With the war's end, he was assigned to England and Germany for three months in 1945, as deputy director of the building construction team of the Technical Intelligence Committee.

Following World War II, Mr. Waterman became a member of the executive staff of the Electrical Testing Laboratories, Inc., in New York City. In 1948 he joined the Westinghouse Lamp Division as staff assistant to the manager of commercial engineering. He was made assistant manager in 1952.

It is, of course, axiomatic that a man who is already contributing so much would be active as well in many other organizations. In addition to his Illuminating Engineering Society activities, Mr. Waterman is a past-chairman of the Lighting Sales Committee of the Edison Electric Institute, and is associated with the American Institute of Electrical Engineers, the International Commission on Illumination, the American Standards Association, the National Society for the Prevention of Blindness, and the French Illuminating Engineering Society.

A native of Summit, N. J., Mr. Waterman, his wife Serena, and two sons Frank and George, now live in Chatham, N. J. Here too he serves — in civic affairs, currently as a member of the Board of Trustees of the Stanley Congregational Church in Chatham. In summer he is a resident of Madison, Connecticut, where his hobby is sailing a 16-foot sloop on Long Island Sound.

Lighting Requirements for Older Workers

By SYLVESTER K. GUTH
A. A. EASTMAN
J. F. McNELIS

It is obvious that our modern work world demands high efficiency of machines, methods and men. Even in this era of increasing automation, many tasks are becoming more complicated and critical. Thus, there is a requirement for continual study to determine how human performance can be maintained and even improved. Most tasks are dependent upon visual abilities of workers. How well they perform — their speed and accuracy — is, among other factors, a function of how well they can see. Statistics show that the average age of our working population is slowly but steadily increasing. It seems prudent that due consideration should be given to provide these older workers with all possible aids so that full and continued use can be made of their acquired skills and abilities. Since vision plays such an important role in their work, it follows that adequate seeing conditions must be provided.

Many investigators have studied the effects of age upon visual processes and other functions of the human organism. Although most of the results have shown a decline in numerous biological functions with increasing age, only a few criteria have been found suitable in visual tests for obtaining useful information applicable to lighting practices.

Weston[1] found a considerable decrement in visual performance (combined speed and accuracy) with age. Older observers attained a greater improvement in performance with increased illumination than younger observers. However, even with the highest illumination (500 footcandles) the older group was unable to achieve the same performance as the younger group did with the lowest illumination (0.5 footcandle). Weston's test involved "quickness of perception," eye-hand coordination and manual dexterity. It should be pointed out that the last two of these factors may limit the performance more than visual perception. McFarland and Fisher[2] found that the final level of dark adaptation is a function of age. For example, for every 13 years of age the intensity of illumination must be doubled to make a minimum threshold target visible to the fully dark-adapted eye. While dark adaptation and threshold conditions are not typical of most visual situations, it is logical to conclude that such effects of age probably also are reflected in suprathreshold seeing.

In a previous paper,[3] an evaluation of experimental data in terms of age groups indicated a definite trend toward the need for higher footcandle levels by older workers. However, an insufficient number of observers, especially in the older age groups, did not make a detailed analysis possible. Furthermore, in this earlier investigation, no specific attention was paid to the refractive condition of the eyes of the observers. Therefore, it was felt desirable to make an additional study in which these factors could be taken into consideration.

In order to create comparable conditions for visibility measurements it was, of course, necessary to create an equal refractive status of the observers in all age groups. Provided that this could be accomplished, one may base the experimental approach on the following premise: any differences of visibility levels obtained by observers in various age groups must be attributed to factors other than refractive differences. Such factors could, for example, be a decrease in retinal sensitivity with age, an increase of optical opacities in the ocular media of the aging individual, a decrease of response threshold in the visual centers with advancing age, or a combination of these or other factors. The present study is only concerned with the *effect* of age on visibility and not with the fundamental causes that may bring about this effect.

Experimental Procedure

Visibility measurements were made with the Luckiesh-Moss Visibility Meter[4,5] by 100 observers, most of whom had never used the instrument before. No special selection of observers was made except to exclude those who had pathological or uncorrectable optical eye defects. The observers included typical office and laboratory workers whose ages ranged from 17 to 65 years. The distribution of ages permitted a convenient grouping

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHORS: Lamp Division, General Electric Co., Nela Park, Cleveland, Ohio.

TABLE I — Average Visibility Levels Obtained by Observers in Various Age Groups for Several Footcandle Levels When Viewing 6-point Type at a Distance of 16 Inches.

Age Group	17-20	21-30	31-40	41-50	51-60	61-65	
Average Age	19	26	36	46	56	63	
No. of Observers	12	17	22	21	21	7	
Footcandles			Visibility Level				Average All Groups
20	3.95	3.86	3.80	3.63	3.38	2.79	3.63
30	4.90	4.80	4.70	4.50	4.12	3.38	4.48
50	6.83	6.67	6.42	6.08	5.48	4.60	6.12
80	9.79	9.68	9.30	8.62	7.20	6.60	8.76

for an analysis of the experimental results. (Pertinent information regarding the groups is presented in Table I.)

In order to determine refractive errors, each observer was checked by a sensitometric method of refraction.[6] This involved an application of the L-M visibility meter which is used in conjunction with a specially designed test object and convergence target. In brief, the technique involves the determination of the lens power required to enable an observer to achieve maximal visibility with standardized viewing conditions. This has been found to be an accurate and useful method for determining refractive errors.[7] The viewing distance of 16 inches in the sensitometric check was the same as that used in the main investigation. Those observers normally wearing glasses for near visual work wore them during the sensitometric examination and during all subsequent test periods. Each observer was provided with additional correction, if needed, as determined by sensitometry. In other words, the vision of each observer was made emmetropic, or so-called normal, for the viewing distance of 16 inches used in this investigation. This is particularly important for presbyopic observers whose normal near correction may be for distances other than 16 inches. Younger observers normally would experience no difficulty because of their wide amplitude of accommodation. Thus, insofar as was possible, all observers were placed on an equal refractive basis.

Each observer made a series of ten measurements of the visibility of ten 7-letter words which contained no letters with ascenders or descenders. Words were selected which were similar near the threshold, such as nervous, concave, measure, etc. They were well printed in 6-point type on white paper. A style of type was especially selected for its simplicity and uniformity of width of stroke. The size, which is slightly smaller than that normally used for text material, was chosen so that visibility measurements would be within the limits of the L-M visibility meter for the footcandle levels

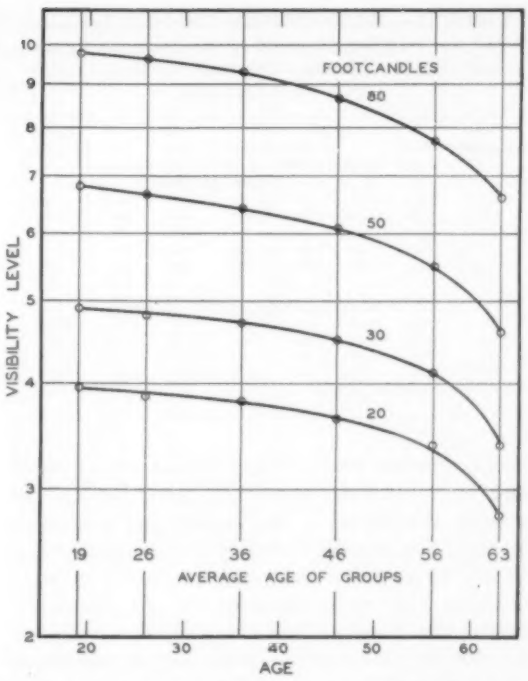

Figure 1. Illustrating the decrease in visibility level of well printed 6-point type with increasing age for several levels of illumination.

used in this investigation. Visibility data are available for various sizes and styles of type.[8] The observers were permitted to familiarize themselves with all words prior to the test in order to avoid a learning process for word recognition during the test. In the investigation the words were presented one at a time in random order and the observer was required to name the word upon recognition. At each presentation the threshold of visibility was determined.

Measurements were made with levels of illumination ranging from 10 to 100 footcandles. Care was taken to insure that the surroundings had minimal effect upon the observations. The visibility data for each observer were plotted and from the resulting curves the footcandle levels necessary for him to obtain visibility levels of 3, 4, 5, 7 and 10 were determined. These footcandle levels have been used for the analyses in this paper.

Visibility at Various Footcandle Levels

The average visibility levels attained by each age group for 4 levels of illumination are presented in Table I and are illustrated graphically in Fig. 1. The decrease in visibility is gradual up to the age of about 45, after which the change becomes more pronounced. The oldest and youngest groups at-

TABLE II — Relative Visibility Levels in Terms of (A) the Visibility Obtained by the Youngest Group and (B) the Visibility Obtained by Each Group With 20 Footcandles.

Footcandles	Age Groups						Average All Groups
	17-20	21-30	31-40	41-50	51-60	61-65	
	A. In terms of youngest group						
20	100	98	96	92	86	71	—
30	100	98	96	92	84	69	—
50	100	98	94	89	80	67	—
80	100	99	95	88	79	67	—
Averages	100	98	95	90	82	68	—
	B. In terms of visibility with 20 footcandles						
20	100	100	100	100	100	100	100
30	124	124	124	124	122	121	123
50	173	172	169	167	162	165	168
80	248	256	245	237	228	236	242

tain a visibility level of slightly less than 7 with 80 and 50 footcandles, respectively. An analysis of the *relative* visibilities of the various age groups in terms of the visibility level of the youngest group (Table II-A) shows that each group has a fairly constant and equal decrease for all footcandle levels. The oldest group has the greatest reduction in visibility, the average being about two-thirds that of the youngest group.

The relative visibilities tabulated in Table II-B, in terms of the visibility level obtained by each group with 20 footcandles, show that all age groups receive the same relative benefits as the illumination is increased. When the illumination is raised progressively from 20 to 30, 50, and 80 footcandles, the average improvements in visibility are 23, 68, and 142 per cent, respectively. It is interesting to note that the improvement obtained when increasing the illumination from 30 to 50 or from 50 to 80 footcandles is about equal, being 37 and 44 per cent, respectively.

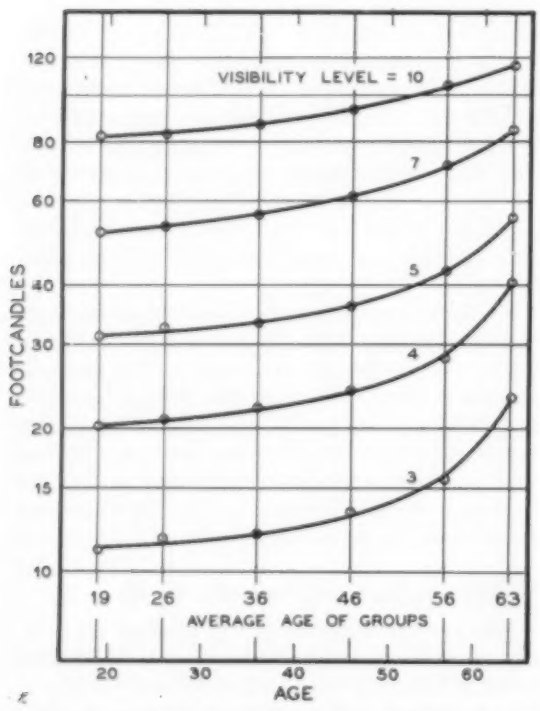

Figure 2. Illustrating the increase in illumination required by various age groups for specific visibility levels. The visual task was well printed 6-point type.

Footcandles for Equal Visibility

Another, and perhaps more practical analysis of the data can be made in terms of the footcandles required for achieving equal visibility. These are presented in Table III-A, and plotted in Fig. 2 for several visibility levels. As in the preceding analysis, illumination remains relatively constant for a specific visibility level until an age of about 45 or 50 when the lighting requirements increase more markedly. Since the older observers, all of whom were presbyopic, were provided with the proper correction for the 16-inch viewing distance, the need for higher footcandles is not considered a function of uncorrected refractive errors.

Approximately 30 footcandles will provide the youngest group with a visibility level of 5. However, the oldest group will achieve a visibility of only about 3.5 with this illumination and required 58 footcandles for a visibility level of 5.

Using the youngest group as a basis of comparison, the next three older groups require 5, 8 and 17 per cent more illumination. It should be noted that these values are fairly constant for all visibility levels. However, the percentage increases for the two older groups become smaller. The values for the 51-60 age group range from 45 down to 28 per cent for visibility levels of 3 and 10, respectively.

TABLE III — Average Footcandles and Relative Footcandles Required by Observers in Various Age Groups to Obtain Several Visibility Levels.

Visibility Level	Age Group						Average All Groups
	17-20	21-30	31-40	41-50	51-60	61-65	
	A. Footcandles						
3	11	12	12	13	16	23	14
4	20	21	22	24	28	40	25
5	31	33	33	36	43	56	37
7	52	53	56	61	71	85	61
10	82	83	87	94	105	117	93
	B. Relative Footcandles						
3	100	100	100	100	100	100	—
4	182	175	183	185	175	174	—
5	282	275	275	277	269	243	—
7	473	442	467	469	444	369	—
10	746	692	725	723	656	509	—

TABLE IV — Footcandles Required to Obtain a Visibility Level of 5 for Each of 100 Observers, Arranged According to Decreasing Footcandles within Each Age Group.

Age Group												
	17 - 20		21 - 30		31 - 40		41 - 50		51 - 60		61 - 65	
	ft-c	Age	ft-c	Age	ft-c	Age	ft-c	Age	ft-c	Age	ft-c	Age
	46	19	74	26	57	36	69	41	105	55	96	63
	42	19	45	28	51	31	62	42	74	57	71	65
	41	20	44	21	50	39	57	50	50	53	62	62
	38	20	43	26	50	34	50	42	50	59	53	61
	34	17	36	21	47	37	46	48	48	56	38	65
	34	19	36	25	45	35	43	46	48	56	35	63
	33	19	36	27	42	40	43	46	48	58	34	63
	24	20	34	21	40	31	43	49	45	60		
	23	20	30	25	36	36	40	44	43	57		
	23	20	28	28	32	32	38	48	42	53		
	19	20	26	23	31	)	33	44	42	60		
	17	20	24	28	29	39	32	49	41	56		
			24	28	28	33	31	47	40	55		
			24	29	28	40	27	50	40	56		
			17	25	27	36	26	49	35	56		
			17	29	24	31	23	49	29	56		
			16	24	23	33	22	45	28	54		
					21	39	20	43	27	52		
					20	34	20	43	24	55		
					17	35	17	41	23	60		
					17	38	15	48	19	55		
					16	33						
Averages	31	19	33	26	33	36	36	46	43	56	56	63
Average Deviation, Per Cent	27	—	31	—	33	—	35	—	28	—	32	—

The differences are even more marked for the oldest group as shown in the following tabulation:

Visibility Level	3	4	5	7	10
Increase in footcandles, per cent	109	100	81	63	43

These values indicate, for example, that about twice as much illumination is required by the older workers for a visibility level of 3, and only half again as much for a visibility level of 10.

The relative footcandle values of Table III-B indicate that all except the oldest group require about the same percentage change in illumination for a given improvement in visibility. These findings are in agreement with the relative visibility data of Table II. However, for the oldest group, a progressively smaller percentage increase in footcandles is required as the visibility level is increased. That is, a doubling of the illumination is more effective for the oldest observers and will provide them with a greater improvement in visibility than the younger groups. This is in agreement with Weston.[9] However, it must be remembered that for a given visibility level, footcandle requirements increase with age and that the base level of relative footcandles is different for each group. The higher footcandle requirements indicate that the older workers need a greater brightness difference,[10] for a given visibility level. Similarly, the greater absolute differences in illumination for visibility levels of 3 and 10 required by various age groups show the need for an increasing brightness difference for a given improvement in visibility. These differences for the oldest and youngest groups are 94 and 71, respectively. These indicate that, for the specific task used in this investigation, the former require a 30 per cent greater brightness difference for the same improvement in visibility.

Differences Among Subjects

Space does not permit presenting all the individual data. However, Table IV which is for a visibility level of 5 is typical for illustrating differences among observers. In this table are presented footcandles for equal visibility related to the age of each observer. They are arranged in order of decreasing footcandles within each age group. As would be expected, the range of illumination requirements for *all* observers is large, being from 15 to 105, with an average value of 37 footcandles. Furthermore, large differences exist among observers within the same age group and among those of the same age. The average deviations within the age groups vary from 27 to 35 per cent. It is interesting to note that a 33-year old observer required the lowest and a 55-year old observer required the highest level of illumination. Despite the scatter of the individual data, a definite increase in lighting requrements with age is indicated by the averages.

The scatter of the data of Table IV emphasizes how much more revealing the data of individual observers are than gross averages. Individual observers generally are very consistent by themselves, as was demonstrated in our previous paper.[3] The same consistency was found in this investigation. Plots of individual curves relating visibility and footcandle level were remarkably parallel. This is shown in part by the group data of Table II-B. Average deviations of individual data are relatively

small and indicate relatively high statistical significance of differences. Similarly, if each observer's data are placed on a relative basis in terms of his footcandle requirements for a visibility level of 3, the average deviations of the age groups are less than 10 per cent. The standard error of the mean would be about 2.5 per cent. In other words, wher subjective differences are eliminated a high reliability of the data is indicated. Nevertheless, the variations among observers of the same or different ages should not detract from the important fact that higher footcandle levels contribute to better seeing.

It must be emphasized that the data obtained in this investigation are for a specific high contrast test object. However, the majority of typical work world tasks involve low contrast and dark background. Therefore, the footcandle levels indicated by our experimental visibility measurements must be considered to be on the conservative side.

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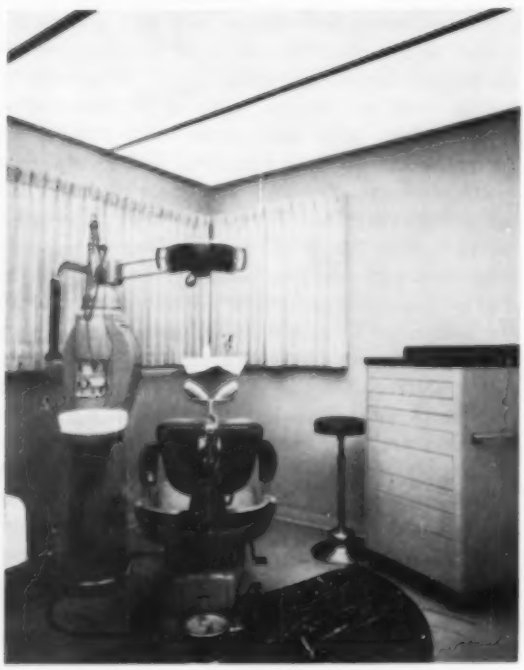

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Luminous Ceiling For a Dental Clinic

General illumination on the order of 140 footcandles maintained is provided by the luminous ceiling installations in the operating rooms of Dr. Arthur P. Gabriel's dental clinic in Greendale, Wis., reducing brightness contrasts with the standard dental lighting unit. Both doctor and patients have found the installation comfortable.

This installation was entered by Richard L. Garber, Lighting Engineer, Wisconsin Electric Power Co., Milwaukee, in the Milwaukee Section's contest for My Most Interesting Lighting Job.

Carbon Arcs for Television Studio Lighting

By R. B. DULL
J. G. KEMP

BACK IN 1946 "BC"—before color—when the television industry was still quite young, carbon arcs were used for studio lighting. Earliest application was of motion picture studio positive carbons for Duracs and spotlights, and later high intensity carbons were used for process or rear projection. In fact, they still are.

Although the spectral characteristics of light sources are of secondary importance in black and white television, they assume primary importance in color television. The spectral requirements of color television and the characteristics of a number of available light sources are generally well known, but recent developments have had considerable influence on the suitability of arc carbons for black and white and especially for color television.

Process Projection

The most frequent application of the carbon arc in television lighting — both color and monochromatic — is as a light source for process or rear projection. It is particularly adaptable to color projection, where a minimum screen brightness of 300 footlamberts is required on the camera side of the projection screen.

Some studios use an 11-millimeter high intensity projector positive carbon, although a 13.6-millimeter carbon with a 4 by 5 inch aperture gives a more favorable distribution of light on the screen, as well as a higher illumination level. The 13.6-millimeter carbon operates in the 125-160-ampere range, and Fig. 1 illustrates the spectral energy distribution of the light from the crater of the carbon when operated at 150 amperes. Still better light distribution can be had by using a 16-millimeter high intensity studio carbon operating in the 150-160-ampere range, although the total screen light may be decreased somewhat because of the lower current density and brightness. The 16-millimeter *super high* intensity studio carbon at 225 amperes has the same current density as the 13.6-millimeter projector carbon at 160 amperes, and its brightness is midway between that of the latter carbon and the regular 16-millimeter studio carbon. It may, therefore, be more advantageous to use it than either the regular studio or 13.6-millimeter projector carbons.

Most of the light for process projection comes from the crater of the positive carbon, with a color temperature in the 5900-6600 K range. The carbons mentioned above can be used without filters for black and white rear projection, and also for color projection if the entire stage is illuminated with the same type of light source. If the stage is illuminated with incandescent tungsten, however, filters must be used with the carbons to reduce their color temperatures so the two types of lights can be mixed without noticeable visual effects. Use of such filters reduces the usable light from the carbon arc by approximately 40 per cent.

Color Modified Carbons

The high light levels required for process projection in color television make the carbon arc very attractive, and a color-modified carbon has been

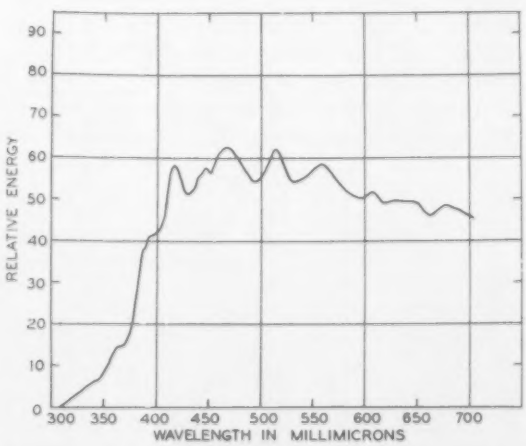

Figure 1. Spectral distribution of light from crater of 13.6-mm carbon when operated at 150 amperes

Based on a paper presented at the 79th semi-annual convention of the Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y., April 30 - May 4, 1956, and published through the courtesy of the Society.
AUTHORS: National Carbon Co., a Division of Union Carbide and Carbon Corp., Fostoria, Ohio.

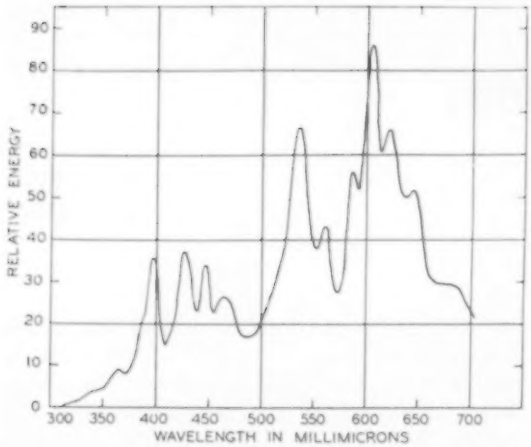

Figure 2. Spectral energy distribution of average crater light from experimental 13.6-mm carbon at 150 amperes.

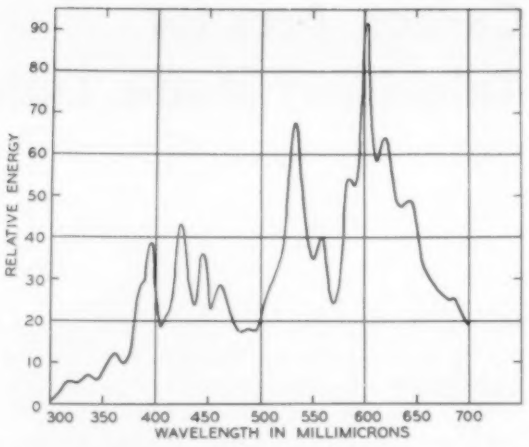

Figure 3. Spectral energy distribution of average crater light from 16-mm carbon at 160 amperes.

developed that can be mixed directly with incandescent tungsten without the use of filters. More generally known as the yellow flame carbon, the new light source is being used by the motion picture industry for both special lighting effects on the set and for process projection. The 16-millimeter super high intensity yellow flame carbon is designed to operate at 225 amperes.

Two experimental yellow flame carbons have been developed for evaluation in television studio lighting. One is a 16-millimeter carbon for operation in the 150- to 160-ampere range, and the other a 13.6-millimeter carbon for operation at approximately 150 amperes. Figs. 2 and 3 give the spectral energy distribution of the average crater light from the experimental 13.6-millimeter carbon at 150 amperes and the 16-millimeter carbon at 160 amperes, respectively. Note the similarity. A flatter curve, that of Fig. 4, is obtained when the 16-millimeter carbon is operated at 225 amperes.

Table I gives additional characteristics of the standard and experimental carbons when used in a condenser-type 35mm motion picture projection lamp with $f/2.0$ optics, and with a 0.600 by 0.825 inch standard 35-mm motion picture sound aperture and an $f/2.0$ projection lens. A 4 by 5 inch aperture is commonly used for process projection in television studios. Apertures and optical systems for motion picture projection differ so widely from those for process projection in television studios that light on the process screen in the latter case cannot be readily calculated from the data in Table I. The data do, however give an indication of what can be expected of the various carbons.

The third column of the table gives the total screen light when the lamp is adjusted for maximum screen light. These figures indicate that the 13.6-mm high intensity projector carbon at 150 amperes produces more light than any of the other carbons listed. The magnification of the optical system, however, is such that there is considerable spill-over of light around the motion picture aperture when 16-mm carbons are used, and therefore a sizeable portion of the light is wasted. Column 4

TABLE I — Screen Illumination with Condenser Type 35-mm Motion Picture Projection Lamp With $f/2.0$ Optical System — 0.600 x 0.825" Aperture.

Carbon	Arc Amps.	Max. Screen Lumens	Usable Light in Lumens	Approx. Relative Screen Light	Side-to-Center Distribution	Relative Radiant Energy Flux at Center of Aperture
13.6-mm projector	150	19,500	11,700*	100	60%	100
Experimental 13.6-mm yellow flame	150	18,000	18,000**	155	70	55
16-mm studio	160	15,900	9,500*	80	55	80
Experimental 16-mm yellow flame	160	15,700	15,700**	135	65	50
16-mm super studio	225	17,600	10,600*	90	70	85
16-mm super yellow flame studio	225	18,900	18,900**	160	70	75

*Assuming 40 per cent filter loss.
**Assuming filtering not necessary.

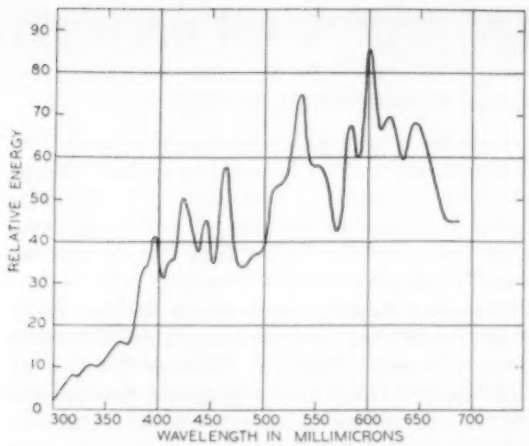

Figure 4. Spectral energy distribution of 16-mm carbon operated at 225 amperes.

shows the usable light produced by each of the carbons, assuming 40 per cent filter loss with non-color-modified carbons, and that no filter is needed with the yellow flame carbon.

Column 5 gives the relative screen light with the 13.6-mm high intensity projector positive carbon as a base. Under the conditions described above, the experimental 13.6-mm high intensity yellow flame carbon produces 55 per cent more usable light than its non-color-modified counterpart. In general, the yellow flame carbons produce 35 to 60 per cent more usable light.

TABLE II — Color Temperature of Crater Light.

Carbon	Amperes	Color Temperature
13.6-mm projector	150	6100 K
Experimental 13.6-mm yellow flame	150	3400 K
16-mm studio	160	6600 K
16-mm yellow flame studio	160	3400 K
16-mm super studio	225	5900 K
16-mm super yellow flame studio	225	4100 K

Column 6 shows that the experimental yellow flame carbons produce higher side-to-center light distribution than do their non-color-modified counterparts. This is probably because of a change in shape of the luminous gas ball in the shallower craters of the positive carbon. Since there is little or no difference in the crater depths of the two super studio carbons, there is no difference in side-to-center light distribution.

Since television techniques call for the continuous projection of a slide for as long as 30 minutes or more, heat at the aperture is an extremely important factor. The last column of Table I compares the relative radiant energy flux at the center of the aperture with that produced by the 13.6-mm carbons.

The color temperatures of the light from the craters of the various carbons are listed in Table II. As previously stated, the color temperatures for non-color-modified carbons are in the 5900K to 6600K range. That of the two experimental yellow flame carbons is 3400K, whereas the color temperature of the 16-mm super high intensity yellow flame

Figure 5. This scene from "The Ten Commandments," Cecil B. DeMille's VistaVision picture for Paramount, illustrates how the motion picture industry uses the carbon arc to create the effect of open shade and give the illusion of a semi-open structure. Loyal Griggs, A.S.C., was director of photography.

Figure 6. The carbon arc is unequalled when it comes to creating sharp shadows, as illustrated in this scene from the Metro-Goldwyn-Mayer picture "Dianne." Robert Planch, A.S.C., was director of photography.

studio carbon is 4100K. The latter color temperature may appear to be too high without filtering, but as indicated above, the motion picture industry is using it for process projection when photographing with 3200 to 3400K film.

All color temperatures in Table II were determined from CIE trichromatic coefficients obtained from spectral energy distribution curves of the crater radiation.

Special Lighting Effects on Stage

In addition to process projection, the carbon arc is a useful light source for creating special lighting effects on the television studio set. It is extremely useful for simulating sunlight where the light level must be considerably higher than that for general stage illumination. Fig. 5 illustrates how the motion picture industry has used the carbon arc to create the effect of open shade and give the illusion of a semi-open structure. Without this special lighting effect the scene would appear flat, and the illusion of a semi-open structure would be greatly reduced, if not lost altogether.

The carbon arc is also capable of creating sharp shadows. At present, no other light source can equal the carbon arc in this respect. In Fig. 6 the shadow pattern of the window lattice is well defined on the wall, not only creating the effect of sunlight streaming through the window, but also giving depth to the screen. The number of special lighting effects that can be created by using the carbon arc in this manner depends upon the ingenuity of the studio lighting engineer.

Acknowledgements

The authors are indebted to Messrs. H. M. Gurin and R. S. Lyons, National Broadcasting Company, for information regarding the lighting requirements of television studios, and for the interest they have shown in the application of color-modified carbons to color television.

I.E.S. Officers and Committee Chairmen

Photos of I.E.S. National Officers and the Section and Chapter Chairmen begin on page 704. Listing of these officers begins on page 18A. The I.E.S. Committees and their Chairmen are listed, beginning on page 24A.

Lighting for Audio-Visual Teaching

By CARL J. ALLEN

THE USE of projector-type educational visual aids has experienced a phenomenal growth during the last few years. As an example, during the period 1940 to 1955 the use of educational films increased six times in the elementary and high schools. In the same period the use of films in the college field increased ten times. With the current general shortage of teachers and overabundance of students, the use of audio-visual material has increased the efficiency of education helping to overcome this unbalanced situation. Audio-visual material is used in many phases of education. In military training the use of sound films and film strips has been an important factor in the success of the many varied training programs. In Sunday morning religious training the use of films and slides is standard procedure in many churches and is a common experience to even the four- and five-year-olds. In industry in the orientation courses and in the technical conferences and the sales and staff meetings visual presentations by projection are extensively used. These are typical examples of the wide-spread use of audio-visual projection material in today's teaching techniques.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHOR: School Lighting Specialist, General Electric Co., Nela Park, Cleveland, Ohio.

Figure 1. The use of educational films is becoming an increasing factor in teaching techniques. Use of films in schools increased six times between 1940 and 1955.

Room Darkening

With the growth of audio-visual education, significant progress has been made in the performance of projectors, the efficiency of projector lamps and the reflectance characteristics of projector screens. The accumulated effect of each announcement of each improvement in efficiency apparently has led to a generally held belief that daylight projection is possible and room darkening is no longer necessary. The goal that motion pictures or slides should be shown in the normal classroom lighting environment is desirable and probably some day will be attained. Under certain limited conditions it can be done now. For instance, a black and white line drawing slide projected on a directional type screen from a high-output modern projector may be reasonably visible with considerable stray light on the screen. As a specific example, the projected image of the black and white line drawing of the young lady in Fig. 2 was still quite visible when over 200 footcandles of stray light was on the screen. In contrast to this, the original color transparency slide of this young lady was quite unsatisfactory in detail and contrast when only 20 footcandles of stray illumination was present on the screen. The projector for this test was a relatively powerful projector and was providing 20 footcandles on a beaded screen and the observer was located beside the projector.

In addition to the various types of projected

Figure 2. An example of the wide range of brightness contrasts which are common in motion picture and slide material.

Figure 3. An individual seated to one side of a projector does not see as brilliant an image on a glass-beaded screen as one who is seated beside the projector.

material another factor which affects the degree of darkening required is the location of the viewer with respect to the projector axis and with respect to the source of stray light on a directional type screen. The effect of this condition is shown in the two views of the same projected slide projected on the same beaded screen, Fig. 3. In one case, Johnny, who is seated to one side of the classroom, sees the image illustrated in the left-hand photograph and may properly complain that the picture is faint and appears washed out. The teacher, who is standing beside the projector, in the most favorable spot, sees an image which is relatively brilliant and has good contrast in the details of the picture. She wonders what is wrong with Johnny's eyes.

The above two examples illustrate how important it is to control the stray light in a room for good projection. The apparent lack of appreciation of this has resulted in many new schools being turned over to the use of the teachers without any provisions for darkening the classrooms. This one point is an often heard complain of the teachers who find it difficult to use audio-visual presentations in their classrooms because of the great amount of daylight which falls on the screen.

In order to understand the problem of audio-visual projection techniques fully, it is necessary to know the limitations and capabilities of modern projection lamps, projectors, and screens and also the importance of proper room darkening and room lighting. The goal of room darkening is to provide controlled dim-out and not complete blackout. Illumination should be subdued and properly balanced, so that seeing is comfortable and attention is directed to the screen. Some illumination is also desirable so that there may be visual contact between teacher and student, and so that simple notes may be taken if desired.

In schools, it is generally conceded that audio-visual presentations should be made in the regular classrooms and that the auditorium or special audio-visual room be used only for very long programs or for large groups. In many of the modern auditoriums there are no windows and the darkening problem does not exist but in classrooms a dim-out daylight control is necessary.

Projectors

There are a number of different types of projectors used in audio-visual teaching; among these the 16-mm projector is the most generally used. The reason is that there is more educational material available on 16-mm sound film than on any other form of film or slide media, and it is constantly increasing. The next most widely used is the 2 x 2-inch projector which can be adapted also for 35-mm slides and film strips. The great advantage of this last projector is the wide use of the 35-mm camera and the ease with which locally prepared slide material can be produced. In some fields of education the 2 x 2-inch or 35-mm slides will constitute the major amount of projected material. In addition to these two, there are three other types of general purpoes projectors which are useful and commonly used. They are the 3¼ x 4-inch slide projector, the opaque projector, and the overhead projector. While the 3¼ x 4-inch size is being supplanted by the more convenient 2 x 2-inch and 35-mm slides, it is still widely used. Because of its larger size it is advantageous where there is a need for hand-colored slides. One advantage to hand-colored slides is that they usually have a higher average transmission than typical color transparency slides and thus a higher screen brightness. This observation is based upon the practical experience of the photographic section at Nela Park which has processed thousands of slides of each type during the last few years. They have found that typical hand-colored slides transmit, on the average, about twice as much light as typical color transparency slides.

While 1000-watt lamps are generally the largest incandescent lamps used in 16-mm and 2 x 2-inch projectors there are projectors for 3¼ x 4-inch slides which use 3000- and 4000-watt incandescent lamps. Such equipment will deliver 4000 to 6000 lumens to the screen. Arc-type projectors for 3¼ x 4-inch slides are also available where high screen lumens are required. Such projectors equipped with 45-ampere arcs will deliver about 7500 lumens to the screen.

The opaque projector and overhead projector are

specifically useful where material is not readily available in film or slide form. Opaque projectors, for example, will project open book pages which may be up to 10 inches square. Although the opaque projector is very useful, it depends upon light being reflected from paper surfaces and produces much lower screen brightnesses than those which project the light through a transparent film. Therefore, when using opaque projectors there should be a minimum of stray light on the screen. In one test of 500-watt projectors, it took 4 footcandles of stray light to wash out the screen image from a standard glass slide; it took only 0.25 footcandle to do the same for the image from an opaque projector.

The overhead projector has the advantage that illustration material can be prepared by hand on large sheets of transparent material without requiring photographic processing. Machines are available which will accommodate transparent material 10 inches square. Black and white line illustrations can be shown in rooms having considerable illumination. Another advantage is that the lecturer can write on a sheet of clear acetate film with a grease pencil. The writing appears as dark lines on the screen.

There are two additional special purpose projectors. They are the micro projectors used in science rooms and the magnifier projector which enlarges ordinary book type to jumbo size for the visually handicapped students. This last is a new visual aid device and is shown in Fig. 4. This magnifier projector overcomes the problem of the visually handicapped students who normally require large type printed books. For the first time it permits these individuals to read any material of customary size type.

Figure 4. A magnifier projector which helps visually handicapped individuals to read ordinary size printed material.

Closed network TV is rapidly becoming an educational tool. In college teaching, for example, it is currently being used to show anything which is too large or too small; or too delicate or too dangerous to be shown directly before a group. A picture viewed on TV differs from the same viewed on a motion picture screen because the TV blacks are blacker with the black glass tubes, hence, stray light is not as serious a limiting factor; also typical TV screen brightnesses will average 10 to 15 times as much as that of a typical 16-mm motion picture. While modern projectors are very effective in projecting clear and brilliant appearing images they are inherently rather low in efficiency from the standpoint of utilization of the light of the projection lamp. For example typical 16-mm projectors may only produce about $\frac{1}{3}$ of a lumen on the screen for each watt input to the projection lamp. The lamps themselves have a relatively high efficiency of about 28 lumens per watt in the 750-watt size. Thus such projectors have an efficiency of about one to two per cent. The 2 x 2-inch and $3\frac{1}{4}$ x 4-inch projectors have approximately three times this efficiency as they do not need shutters and the aperture openings are not as restricted as the 16-mm film aperture. Typical projectors of the 2 x 2-inch and $3\frac{1}{4}$ x 4-inch category range between $1\frac{1}{2}$ and 2 lumens per watt with efficiencies of 5 to 7 per cent. An opaque projector only produces about $\frac{1}{10}$ lumen per watt. The opaque projector is inherently the lowest in efficiency (0.3 per cent), since the light of the lamp must be reflected from a diffused reflecting surface such as the page of a book; in all the other higher efficiency projectors, the light from the filament is directed by the lens system through a transparent medium of varying density or color.

Projection Lamps

A projection lamp standardization program of the recent years has reduced the number of commonly used projection lamps, such as used in school projectors, from over 100 types down to seven lamps shown in Fig. 5. These seven will lamp at least 80 per cent of the modern projectors used in schools. This standardization means, for one thing, that fewer lamps are necessary in the audio-visual center stock room. It also means better lamps, as manufacturing facilities can concentrate on less diversified production and thus improve lamp quality.

Only those lamps for which a projector is specifically designed should be used in that projector.

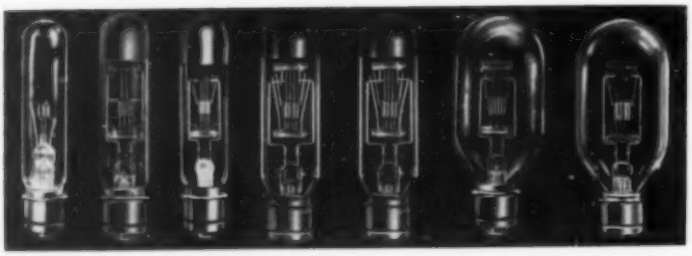

Figure 5. Eighty per cent of modern projectors may be lamped with these seven projector lamps.

Limitations of the optical and ventilation system of the projector limits the wattage of the lamp that can be used in a projector. Increasing the wattage of a lamp past a certain point may not significantly increase screen illumination. This condition occurs when the projected image of the projection lamp filament becomes larger than the film aperture. In addition, overwattage might seriously overtax the ventilation system and cause trouble from excessive heat.

Because projection lamps operate at high luminous efficiencies, the temperature of the filaments, in most cases, is within a few hundred degrees of the melting point of tungsten. The typical projection lamp currently used has a 25-hour life. The 10-hour life lamp will deliver from 15 to 25 per cent more light to the screen than the 25-hour life lamp. Information regarding the recommended lamp or lamps which should be used in any specific projector is available from the manufacturer.

Screens

There are three basic types of reflected-light screens that are in common use today. They are the glass-beaded screen, the processed metallic screen, and the white-mat screen. Each has its own use. If this use is not fully understood, the condition can easily arise, as was discussed earlier, where the teacher was viewing a very acceptable picture while a student sitting a few feet from her complains that he can hardly see the picture. A close-up view of the three types of screens is shown in Fig. 6. The series of three photos compares the brightness of the screen: (1) from the position of the projector, zero-degree viewing; (2) from a position slightly to one side, 22-degree viewing; and (3) from a position at a rather wide angle, 45-degree viewing. It is seen from these illustrations that brightnesses of the screens vary widely with the angle of view from the projector axis. The angle of 22 degrees is the angle at which the typical beaded glass screen and white mat screen have about the same brightness. At 45 degrees the mat white screen is brightest and the beaded screen and processed metallic screen are about the same brightness.

The processed metallic screen is designed to reflect the light within a relatively small vertical angle, but to disperse the light in a rather wide horizontal angle. This is desirable when one considers that individuals are generally seated in a similar pattern fanning out from the screen. The processed metallic screens, available in specially-processed silver and finely-ribbed aluminum, are available only in flat panels. The beaded screens have the advantage of being able to be rolled up

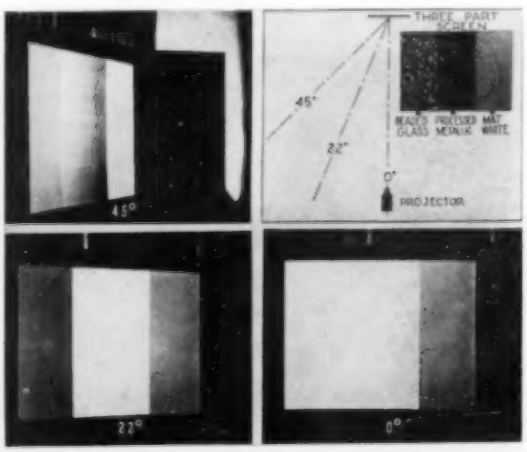

Figure 6. Three views of a demonstration screen which show the relative brightnesses of a glass-beaded screen, a processed metallic screen and a mat white screen at 0-, 22-, and 45-degree viewing angles.

and thus are more portable. For widest angle picture projection, the white-mat screen is best.

The beaded-glass screen has the property of directing light back on the axis from which the light came originally. Thus the most brilliant image is seen from the projector position. Stray light from the window also is reflected back on itself and thus someone seated with his back to the windows will be disturbed the most by the reflections of the stray light from the windows. It is the combination of these two effects which explains why the image that Johnny saw was so faint and washed out in appearance as compared to the sharp and brilliant image the teacher was receiving.

The size of the screen for classroom use is generally specified as one-sixth of the maximum probable viewing distance. Usually a square screen is suggested, in order that horizontally and vertically framed slides may be projected equally well. The ratio of one-sixth is based upon consideration of seeing small details on the screen. In typical school classrooms a student can be seated about 30 feet from the screen and thus a 5-foot wide screen is desirable. When there is no small detail as in viewing travel films the maximum viewing distance based upon this ratio can be increased. In some classrooms, 30-inch screens are used with the students seated closer to the screen. One natural advantage of the smaller screen is that significantly higher brightnesses can be obtained. For example, the brightness of a 30-inch wide screen will be four times the brightness of a 5-foot wide screen when the same amount of light is projected upon both. This increase is inversely proportional to the areas of the projected image.

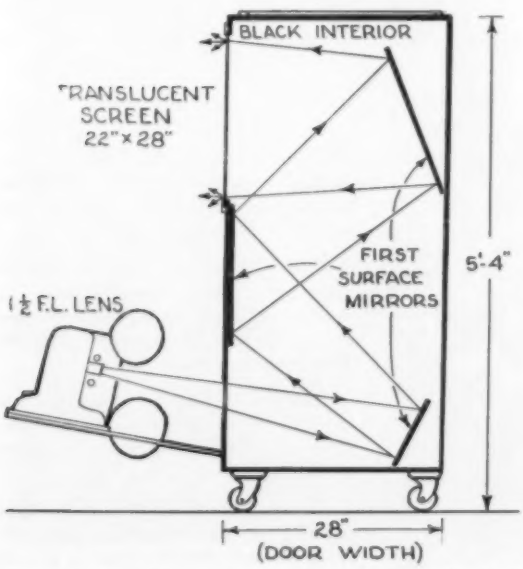

Figure 7. Portable rear projection enclosures. Much of the stray light incident on the translucent screen is absorbed by the black interior of the box.

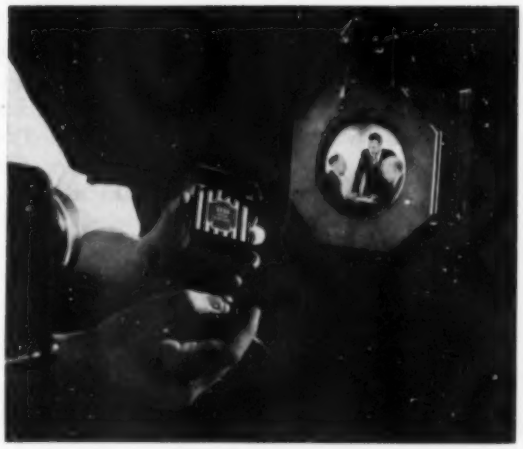

Figure 8. A dim ultraviolet image projected on this experimental light amplifying screen is brightened ten times by applying a voltage across the special phosphor surface.

One projection device which has been used in schools has been the portable rear projection boxes, Fig. 7. The size of such an enclosing box is generally limited by the clearance width of typical classroom doors through which it must pass. In a similar manner to the TV screen, much of the stray light which is incident on the translucent screen is transmitted through the screen and is absorbed in the black interior. Older types of translucent screens were rather narrow in their viewing angle. Translucent screens with specially-processed surfaces are now available, however, which perform similarly to the processed metallic screens.

A new type of screen may someday evolve from the light amplification principle announced by the General Electric Research Laboratory in 1954. In this new avenue of research progress an ultraviolet source in an ordinary lantern slide projector projects a slide onto a special screen coated with a phosphor film, Fig. 8. When an electric voltage was applied to this special screen in one demonstration the brightness of the projected image increased ten times. Further research in the phenomena of solid-state light amplification may sometime in the future help solve the problem of projecting pictures under ordinary room illumination. However, because of the need of further development of the device, it is not in itself, offered as a solution at the present time.

Room Darkening Devices

The trend today is not to blackout the classroom for audio-visual presentations, but merely to reduce the amount of daylight which might strike the screen and wash out the projected image. The results of one investigation, Table I, show the amount of stray light coming from the windows, which make a typical projected picture unsatisfactory. The criterion used by the observers was that the picture was unsatisfactory if significant details, which were clearly present under darkened conditions, were lost when the stray light was excessive. These figures show that only a few footcandles of stray illumination will produce the washed out effect as seen by a student seated to the side of a classroom as illustrated in Fig. 3.

The simplest room darkening is accomplished through the use of roller shades or opaque material which overlap the windows by at least 6 inches. While these shades are usually black, they need not be, as long as they are essentially opaque. They may be any light color which harmonizes with the room interior.

The room-darkening device which seems to have met with the most favor is the drapery which can be drawn on curtain tracks over the entire face of the windows. There are glass fiber base plastic draperies available which are fire resistant and which have excellent wear-and-tear-resistant properties. Draperies work especially well with unit window ventilators located beneath the windows. By having the bottom of such draperies hang in "U" shaped channels on top of the ventilators annoying light leakage beneath the draperies is eliminated. One reason why the draperies are popular is that they can be drawn across the windows as fast as one can walk the length of the classroom. The use of nylon rollers has reduced the friction of draw drapery hardware. Draperies have also been used on curtain tracks which are located about 18 inches from the windows with 12-inch or 18-inch clearance from the floor, so that the windows may be left open for ventilation. This scheme works best on windows which do not receive direct sunlight.

In addition to the use of draw draperies, glass-block lighted rooms may be darkened by double-hung roller shades which are mounted at the division between the glass-block area and the vision strip. One set of roller shades can be pulled up over the glass blocks and the other set pulled down over the vision strip.

Where complete darkening is desired, roller shades should be confined in light-tight side and

TABLE I — Permissible Stray Light on Beaded Screen from Window Area.

Projector 3 1/4" x 4", 2 5/6" diam. lens, 16" E.F.

Lamp Size	Screen Illumination	Screen Brightness ft-L		Maximum permissible stray illumination on screen* ft-c	
		Observation location (degrees from projector-screen axis)			
watts	ft-c	0°	22°	0°	22°
750	24	90	20	25	6
500	18	70	15	18	4
300	9	35	7	10	2
200	4	15	3	5	1
500†	0.5	2	0.5	2	0.5

*Hand-colored slide of light-colored interior scene in projector.
†Opaque projector with white card in projector for screen-brightness values and a photograph in projector for stray light evaluation.

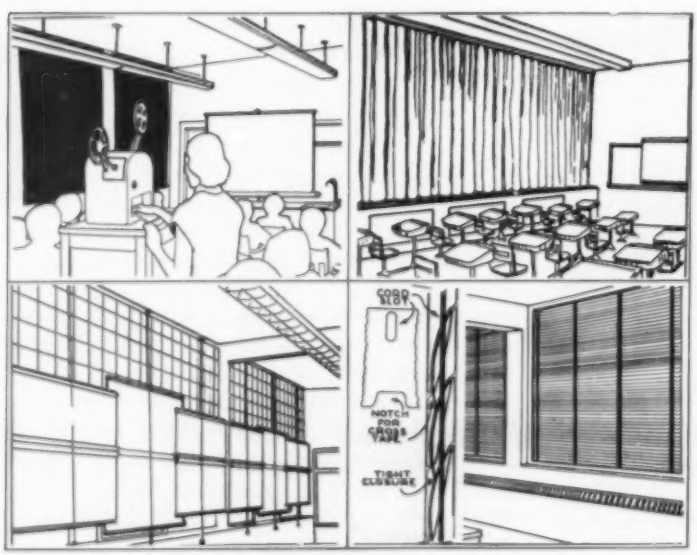

Figure 9. Top left — Opaque roller shades which overhang the windows by at least six inches offer the simplest means of room darkening.

Bottom left — Overlapping double hung roller shades provide means of darkening glass block lighted classrooms and also provide daylight brightness control.

Top right — Draw draperies provide a quick means of darkening a room. They also have an acoustical and decorative value.

Bottom right — Full closure type venetian blinds mounted in light trapping side and bottom channels provide dim-out and daylight glare control.

bottom channels. In lecture rooms where darkening is frequently required, roller shades may be operated by electric motors controlled with limit switches. Skylights can be darkened by horizontal roller shades which are help close to the opening by tight wires over which the roller shade slides.

Recent developments in the design of venetian blinds have produced a blind which closes with very little light leakage. When used in conjunction with light-tight side and bottom channels, these full-closure venetian blinds are a very effective means of room darkening. They also serve very well for the purpose of normal daylight brightness control.

Room Lighting

It may seem paradoxical that after the room has been darkened the next consideration is to provide light in the room; however, it is generally agreed that a completely dark surrounding is not comfortable for viewing projected audio-visual material. The contrast between the screen and its surround is too great. On the other hand, too much surrounding light detracts from the projected images and if it falls on the screen it dilutes the sharpness of the projected image.

Figure 10. A dimmer-controlled indirect light on a projector cart can provide a soft light in a room during projection.

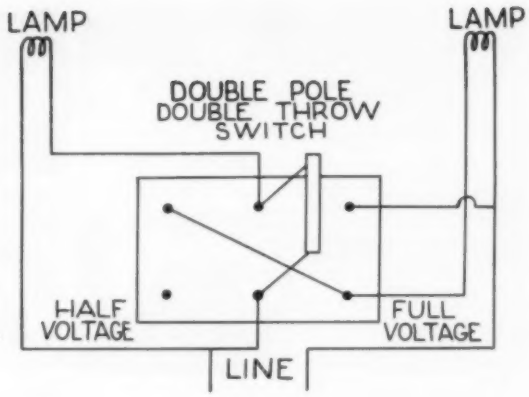

Figure 11. Series operation of like wattage incandescent lamps reduces their light output to about 10 per cent of that at normal voltage.

Most existing rooms probably will have no provision for dimming the existing lighting system, and a portable system is desirable. One way of accomplishing this is to use an indirect light which is part of the projector cart. The indirect reflector lamp shown in Fig. 10 is controlled by a small variable autotransformer so that the illumination in the room can be varied from a footcandle or so to complete darkness. About one footcandle seems about as much as is normally desired. The exact amount will vary with the type of slide being projected, the type of projector, the type of screen and the position of the observer in relation to the screen.

In new construction where incandescent lamps such as the silvered bowl lamps are to be used for general lighting, a double-pole double-throw switch can be used to provide dim-out lighting by placing two of the lamps of the room in series. (Fig. 11.) Series operation of incandescent lamps is equivalent to operating the lamps at 50 per cent of rated voltage, which results in a light output of about 10 per cent of normal light output. Thus, if 30 footcandles are provided in a typical classroom with six silvered-bowl lamps, about one footcandle ($^1/_3 \times {}^1/_{10} \times 30$) is provided when the two rear lamps are operated in series and the four front lamps are turned off. The double-pole double-throw switch for this purpose should be conveniently

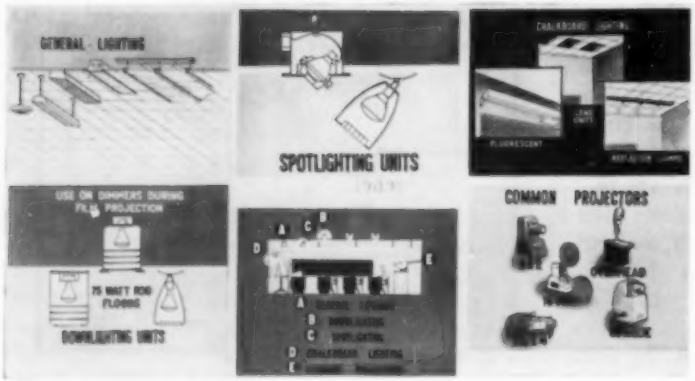

Figure 12. Examples of the various types of lighting which help make visual teaching more effective.

located in the rear wall of the room, near the probable projector location.

One audio-visual lighting scheme which has worked out very satisfactorily is a downlighting system in which the light is confined just over the seating area, Fig. 12. In a typical case with 75-watt R30 reflector lamps on 6-foot centers and operated at full voltage, the system will provide about 5 to 10 footcandles. This is too much disturbing light for viewing typical projected pictures. The white page of a notebook becomes too bright in contrast to the brightness of a typical picture on the screen; further, the full brightness of the lamps, even when fairly well shielded, produces a sense of overhead glare under darkened-room conditions. When these same lamps are reduced in output by a variable autotransformer so that about one footcandle is provided on the desks, then the lighting arrangement has been found to be comfortable from the standpoint of brightness balance of notebook and screen. The reduced filament brightness also reduces the possibility of overhead glare. With this arrangement, there is very little wash-out effect from stray light on the screen as the light is confined principally to the seating area.

The supplementary lighting shown in Fig. 12 is designed to make the chalkboard, display material, and table top demonstrations more effective from an educational standpoint. Accent lighting on these teaching areas makes details easier to see. For persons seated in the rear of the room, it may make the difference between seeing and not seeing some detail being shown. Even more important, the use of supplementary lighting creates a stronger visual impression of the lesson point which has a better chance of being remembered.

In many lecture rooms there are no windows. The windowless lecture room shown in Fig. 13 is lighted by rapid-start fluorescent lamps which can be dimmed by the use of thyratron type dimmers. Controls are located at the rear projection booth and at the speaker's platform. Experience in this room has shown that the general lighting is dimmed to about one footcandle for typical motion picture and slide presentations.

There are occasions when the instructor may wish to write in the dark at the time material is being projected on the screen. This is possible by using a "black-light" chalkboard. The reflector above the chalkboard shown in Fig. 14 utilizes a commercially available fluorescent chalkboard lighting reflector. Instead of the regular fluorescent lamp, it is lamped with a 40-watt black-light fluorescent lamp equipped with a black-light filter. Using fluorescent chalks in the various available brilliant colors, writing in the dark can be very effective and dramatic.

Figure 13. A thyratron tube dimming circuit controls the rapid-start fluorescent lamps in the recessed troffers in this conference room.

Figure 14. The use of a black light fluorescent lamp with fluorescent chalks permits effective and dramatic writing in the dark.

In the industrial lectures and conferences, the speakers will generally be specialists in a field, but not necessarily trained instructors. Most such speakers will use notes or outlines. The speaker's stand shown in the illustration, Fig. 15, has good lighting from both sides onto the notes. The stand is also motorized to adjust for the difference in height of a five-foot, two-inch woman to a six-foot, two-inch man. This variability of height is a visual consideration as some individuals may not be able to see their notes well if they are not at the right distance.

Figure 15. A speaker's stand which gives good illumination on the notes aids a speaker to make an effective presentation. The transilluminated variable speed speech prompter shown at the left assists the speaker inconspicuously in presenting verbatim addresses.

A new speaker's aid is the illuminated adjustable speed speech prompters which were first widely used for TV performances and now are available in a small portable form for use on a typical rostrum. An example of such a device is also shown in Fig. 15.

Illumination on a speaker's notes also throws a pleasing glow up to the speaker's face, if there is also some light on the speaker from above. A good location for overhead spotlights is on a line 55° above the horizontal from the speaker's face. This location gives pleasing facial shadows and yet is not glaring to the speaker. Two spotlights, with one slightly stronger than the other, located about 90° apart in the horizontal plane is considered good practice for lighting speakers. Preferably such spotlights should be dimmer controlled.

Visibility of Audio-Visual Material

One additional consideration in the audio-visual picture is the preparation of slide material for good visibility. Too often when one wishes to illustrate a talk, illustrations in articles or books are copied directly for slide use. This frequently results in too much material with too small detail.

When one considers the preparation of material for a slide, one is concerned with the size of lettering that should be used and with the thickness of lines if graphs or curves are involved. The information shown in Fig. 16 is designed to give guidance in this respect. Letter sizes and line widths are given in terms of height of the illustration.

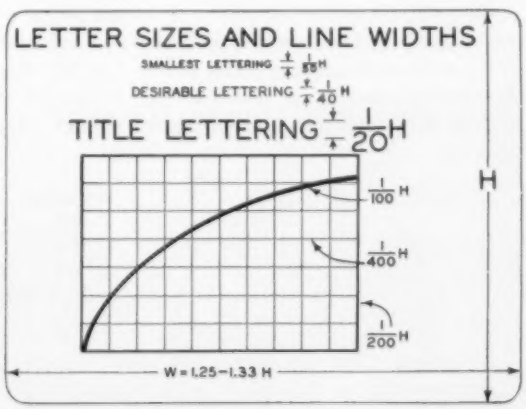

Figure 16. A guide for determining letter sizes and line widths for graphs which will assure good visibility under typical projection conditions.

Thus, if the available letter sizes are known, the height of the drawing may be determined. If the size of the drawing is known, then the ratio of letter height to drawing height gives the minimum-size letters which should be employed. The smallest lettering ratio of $^1/_{50}$ of H is based upon a minimum projected-letter height of one inch for each 30 feet of viewing distance. The typical AMA eye chart which is used for vision screening is roughly based upon a normal person with 20-20 vision being just able to see letters of one inch height at 50 feet. Thus the $^1/_{50}$ H ratio considers the fact that everyone does not have 20-20 vision; hence, for some people the size of leters needs to be larger.

The assumption is made that a screen width equal to $^1/_6$ the maximum viewing distance will be used during the projection of the material. A convenient way of checking the relative visibility of letter sizes and line widths is to view the drawing or chart at a distance six times the width of the chart.

There are many convenient means of lettering charts. Charts may be hand lettered or may be mechanically lettered by devices such as the Wrico or Leroy lettering guides. For dramatic three-dimensional lettering, molded letters of various styles are available. Pre-cut gummed paper letters, available in a wide range of sizes, offer a convenient, neat and easy means of providing legible lettering for charts. Under certain conditions, the typewriter can be used. The electric typewriter is naturally best, because of its controlled pressure, and when used with carbon paper ribbon can give good results. For example, if pica size type is typed on a 3″ x 4″ card and photographed for slide purposes, the size of the resulting letters projected on the screen will give good visibility for typical viewing distance.

In audio-visual centers where slides are prepared and maintained or assembled for various types of talks, a transilluminated panel is very helpful. The transilluminated panel shown in Fig. 17 is part of a table drawer so that it is convenient for use when needed.

Figure 17. Transilluminated panel built into a table drawer for a slide service center. Four 13-watt, 21-inch ⅝-inch diameter deluxe cool white lamps are located on 3-inch centers and 1¾ inches back of a flashed opal glass panel.

Today a wealth of good quality visual educational material exists and there are many efficient visual aid devices to help the instructor in more effective and more efficient teaching. Research has repeatedly shown that the use of audio-visual projected material improves the rate of understanding and increases the retention of the material being taught. With the trend toward greater use of such material, greater planning is necessary in the design of instructional areas to make audio-visual teaching as easy to use and as effective as possible.

Acknowledgments

Appreciation is expressed to the following companies for use of the indicated illustrations: Ansco for use of the original Anscochrome from which Fig. 2 was derived; American Optical for Fig. 4; Hunter-Douglas Corporation for Fig. 9, lower right; and Underwood Corporation for Fig. 15, left illustration.

INSTALLATION AT MASLAND DURALEATHER, AMBER AND WILLARD STS., PHILADELPHIA, PA.

Lighting for Color Matching Fabrics

LIGHTING OBJECTIVE: To provide a high level of illumination for color matching vinyl plastic fabrics.

GENERAL INFORMATION: The color matching room shown is 14 feet by 18 feet 6 inches. Colors and reflectances are as follows:

	Color	Reflectance
Ceiling	Black	1%
Walls	Black	1%
Floor	Black	8%*

*High reflectance due to dust and dirt.

INSTALLATION: Twenty industrial fluorescent luminaires (Day-Brite Lighting Inc. catalog No. 40281 NB) are suspended 4 feet 6 inches above the 3-foot high inspection table as shown in Fig. 2. Each luminaire is equipped with two 40-watt T-12 standard cool white preheat starter type fluorescent lamps (Sylvania Electric Products, Inc.). After trying various other lamps this lamp has been found best suited for color matching the vinyl plastic fabrics. Only yellow and maroon color fabrics are not easily matched.

(over)

A.I.A. File No. 31-f

Lighting for Color Matching Fabrics (Continued)

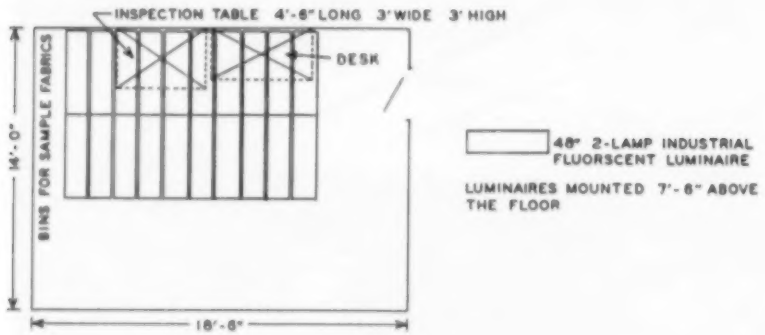

Figure 2. Plan view.

Lamp replacements are made every six months.

The average illumination on the inspection table is 300 footcandles. Brightnesses are as follows:

luminaire		
longitudinal	at 45°	1850 ft-L
crosswise	at 30°	1100 ft-L
ceiling		**
walls		**
floor		**

**Too low to measure.

Lighting designed by Edwin S. Marshall, electrical engineer, Masland Duraleather.

Lighting installed by Masland Duraleather Operating Maintenance Department, Edwin S. Marshall, electrical engineer in charge.

Lighting data submitted by Richard D. Kindt and George T. Anderson, Jr., Lighting Engineers, Philadelphia Electric Co., 211 South Broad St., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Some Factors That Influence the Design of Daytime Effective Exposed Lamp Signs

By A. L. HART

THERE IS always a demand for new and different electrical advertising techniques. Many effects are used after dark, and new developments are rapidly being put into practice. However, for most locations circulation is greater during the day. Thus electric signs with daytime and night-time effectiveness represent a great opportunity for the advertiser. They can also bring a greater return on a given sign investment. High-candlepower light sources in exposed-lamp signs is one method of obtaining this desired effect. While daytime signs have been developed in the past, today there is new interest — partly as a result of the wide variety of reflectorized lamps now available. Already some signs of this type have been installed. While successful, their design has been based on experiment and observation. Thus there is an urgent need for design data.

Present information on exposed-lamp sign design for night viewing, as given in the *IES Lighting Handbook* and other publications, has as its basis, fundamental data that were first presented by C. A. Atherton[1] early in the 1920's. These data concerned the apparent size of a spot of light, when viewed at night, as a function of the end-on candlepower of the lamp, total sign candlepower, viewing distance, and background brightness.

From this were developed rules for predetermining letter proportions for legibility, lamp spacing, and lamp wattage using exposed lamps in the 6- to 100-watt range and comparatively dark backgrounds. This paper will present some basic data and observations relating to signs employing high candlepower sources against much higher brightness backgrounds for daytime effectiveness.

Previous Daytime Electric Signs

Effective daytime electric signs are not new. In 1926 a sign designed by W. M. Potter was installed on the General Electric Store, on Central Pier, Atlantic City.[2] It consisted of "cut-out" letters, faced with ribbed glass. Behind the glass of each letter was mounted a 200-watt lamp in a polished parabolic reflector. The whole unit was mounted on the building front, facing the approach to the Boardwalk. Voltage on the lamps was reduced at night to reduce excessive brightness and to increase legibility at a distance. Two groups of lamps of equal wattage were connected in series to provide 60 volts across each lamp. Other similar signs followed, including one in Cleveland using traffic light type prismatic lens plates in front of the lamps.

Also in 1926, an electric scoreboard was erected at Soldiers Field. The changeable numbers were formed by spots of light in several lamp banks similar to the old carriage call. Each lamp in a bank was covered by a Fresnel lens plate and backed by a reflector. It proved very effective under daytime conditions. The lamp bank type of sign is used today for time and temperature indicators and traveling message signs, usually incorporating sign or general service lamps, but without reflector or lens.

In 1954 a large time indicator or numeral clock was incorporated in the Coca Cola sign aimed down Chicago's Michigan Boulevard. Lamped with 75-watt PAR-38 spotlamps, the clock has excellent attraction power during the day. At night the voltage is reduced to 60. Several smaller theater and hotel signs in the Chicago Loop district, such as the Clark Theater, are using 25-watt 60-volt PAR-38 floodlamps in channel letters for both day and night viewing.

Spot Size Fundamental Factor

Atherton found that the apparent size of an exposed light source when seen at a distance was the key to sign design. If the size of the spot of light could be determined, one could predict whether letters, numbers, or even complicated designs, would be legible or recognizable under a given set of conditions. As shown in Fig. 1A a distant light source appears larger than it really it. This phenomenon is called irradiation.[1] When lamps are spaced so

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHOR: Application Engineering, Large Lamp Dept., General Electric Co., Nela Park, Cleveland, Ohio.

the spots just touch, the letter stroke will look like a continuous series of spots as in Fig. 1B. When spaced to overlap as in Fig. 1C the impression will be a smooth, solid line.

The apparent size of the spot at night is:

Increased by:

(a) raising candlepower
(b) reduced background brightness
(c) greater viewing distances

Reduced by:

(a) total candlepower of the sign
(b) atmospheric absorption

Spot size can vary greatly as in Fig. 1D. Thus, if a letter is designed properly it might appear as in Fig. 1E, but if spot size increases too greatly it may become hard to read, Fig. 1F, or even merge into a solid mass of brightness.

On the other hand, as one approaches from a great distance, the mass of brightness helps gain attention to the sign location. Closer, the mass may begin to take recognizable shape before the letters are legible. Still closer the letters become clear, and when one is sufficiently close, the individual lamps can be distinguished.

Usually the maximum and minimum viewing distances are limited so that the letters can be designed for good legibility and smooth appearance throughout a given viewing range.

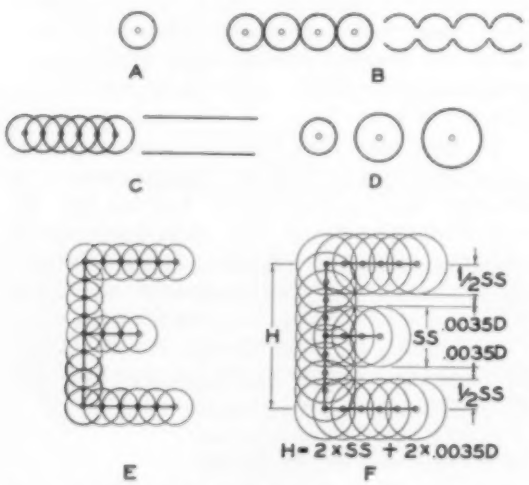

Figure 1. Examples of irradiation — center dot represents actual lamp size.

A — Single lamps.
B — Row of lamps — spacing equal to spot size.
C — Row of lamps — spacing equal of ½ spot size.
D — Variation in spot size.
E — Letter designed for smooth line at minimum viewing distance.
F — Same letter as it would appear at maximum viewing distance.

Signs designed for night viewing usually must contend only with brightnesses from other light sources in the immediate vicinity. Daytime effective signs, on the other hand, must function effectively throughout extreme background sky brightnesses, ranging from several thousand footlamberts during a bright day to the black of night.

Thus, the basic purpose of this investigation was to determine spot sizes under daytime conditions so that letter heights and spacing can be calculated for simple block letters. From Atherton's data the formula for minimum letter height for legibility is

$$H = 2\,(SS) + 2\,(.0035D)$$

where H is minimum letter height in inches,

SS is spot size in inches,

D is maximum viewing distance in feet.

This is based on the letter "E." The factor .0035 is the resolving power of the average eye in inches per foot (approximately one minute of arc) and there are two spaces to be resolved. Spot size is multiplied by two because the center stroke counts as a full spot and the upper and lower stroke as half each as shown in Fig. 1F.

The letter height thus calculated should be multiplied by two for advertising effectiveness. The simplified guides given in *IES Lighting Handbook, Second Edition*, page 11-3, are based on the above formula.

The use of the spot-size technique also affords a means of predicting the legibility of script letters, Old English, etc., and of monograms and special shapes. In these cases, adjacent parts of the design must be separated by a space equal to $.0035D$ for minimum legibility. For effectiveness, this separation should be at least doubled.

Corollaries to the main investigation were determining the approximate candlepower needed for effectiveness, and investigating when and how the candlepower should be reduced at night.

Test Set-Up and Equipment

To determine apparent spot size, apparatus was needed that would vary the spacing of a row of lamps. In this way spacing could be decreased until the spots appeared to touch. The spacing between lamps would then be the apparent spot size.

The test equipment (Fig. 2) consisted of five lamp-holders mounted on a 20-foot channel and moved together or apart by motor-driven threaded rods. The center lamp-holder was held stationary. The drive mechanism was arranged so that the inside lamp-holders moved at eight inches per minute and the outside ones traveled at 16 inches per minute so that the spacing between lamps was al-

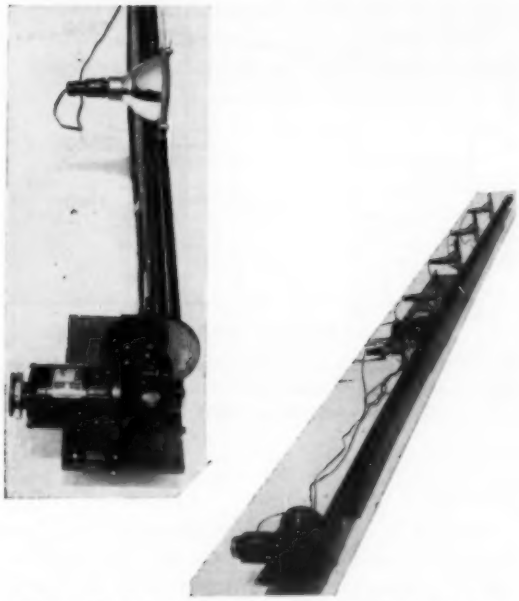

Figure 2. Lamp track used to determine spot size.

ways equal. A tubular "peep sight" was fastened to the center lamp so that the unit as a whole could be aimed.

An adjustable letter "E" was constructed of wooden two-by-fours with sockets mounted on six-inch centers. In addition to experimenting with the skeleton letter, eighteen-inch wide cardboard was used behind the lamps to determine the effect of light or dark letter stroke.

Both track and letter were mounted on the roof of a three-story building. (Fig. 3.) It was found that they could be clearly seen from three different locations. The distances of 1100, 2500, and 4300 feet from the roof to these locations were determined from a U. S. Geological Survey map and a city zoning map. It was not possible to find convenient observation points that lay in a straight line, so the equipment had to be re-aimed for each distance.

Lamps used and their maximum average candlepower are shown in Table I. PAR-38 lamps were used for this test because a suitable range of candlepower is available and they are one logical light source for this application.

Test Procedure

The letter "E" was erected on the roof and observed from the three locations with various lamp types and spacing. It was found that the black letter stroke was, in general, more effective than either the skeleton letter or white stroke. There was also no apparent change in spot size (as there

TABLE I — Average Maximum Candlepower of Lamps Used in Test.

Lamp	Approx. Initial Avg. Maximum C. P.*
A 25-watt PAR38/FL	450
B 75-watt PAR38/FL	1,700
C 150-watt PAR38/FL	3,400
D 75-watt PAR38/SP	4,000
E 150-watt PAR38/SP	10,500

*C. P. in central 5° zone for SP distribution and in central 10° zone for FL distribution.

is at night) when additional candlepower was introduced close to the observer's line of sight. From this it was concluded the total candlepower of a sign would have little effect on spot size under daytime conditions.

The lamps in the letter "E" were merely screwed into sockets in a manner similar to that in an actual sign. No attempt was made to aim each lamp so that the maximum candlepower was directed at the observer. Since no difference in spot size was apparent, it was concluded that the small variation in the axial alignment of the lamps would not appreciably affect spot size. This was substantiated in later tests. For this reason, average maximum candlepower values rather than absolute maximum candlepower were used throughout the investigation. The effectiveness of the various lamps at 6-, 12-, and 18-inch spacing was determined at each observation point. This eliminated some unnecessary set-ups later and resulted in Table II.

The main portion of the test involved the following procedure. The lamp track was aimed toward

Figure 3. Observer's view of lamp track at 1100 feet.

TABLE II — Attraction Power of Lamp Types. (Viewed Perpendicular to Plane of Sign)

Lamp	Spacing (in.)	Distance (ft.) 1100	2500	4300
25PAR/FL	6	F	P	NR
	12	P	NR	NR
	18	—	—	NR
75PAR/FL	6	E	E	G
	12	G	G	F
	18	—	—	NR
150PAR/FL	6	*	E	E
75PAR/SP	12	*	E	G
	18	—	—	F
150PAR/SP	6	*	E	E
	12	*	E	E
	18	—	—	E

— Spacing Inadequate.
* Brighter than normally necessary.

E = Excellent
G = Good
F = Fair
P = Poor
NR = Not Recommended

the observation point so that the plane of the lamp rims was perpendicular to the observer's line of sight, and he was, therefore, in the main beam of all the lamps.

At the observation point, sky brightness and weather conditions were recorded. At a signal from the observer (paddles sprayed with daylight fluorescent paint were used as signals), the lamps were brought together until they were considered just tangent (Fig. 1B) by the observer. The lamps were stopped and the spacing recorded. Then they were moved apart and the procedure repeated. After three to six readings, another lamp type was installed. No specific order of lamps was followed so that variations in spot size would not be anticipated. Five lamps were used to obtain a more easily readable average effect of tangency.

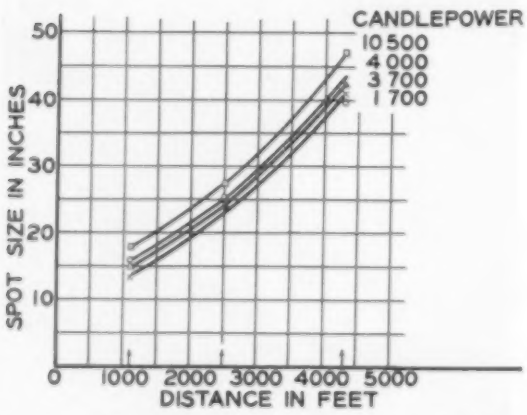

Figure 4. Spot size vs. distance. Four lamps of different candlepower. Clear weather, very light ground haze, background sky brightness—3100 to 4900 footlamberts

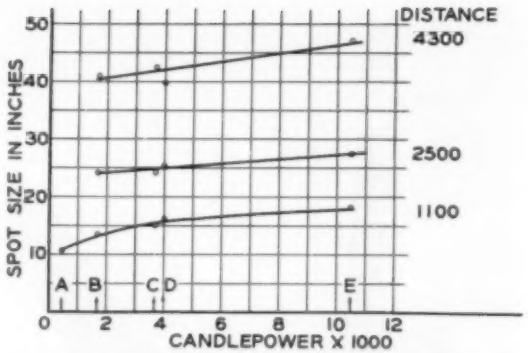

Figure 5. Spot size vs. candlepower for three distances. Clear weather, very light ground haze, background sky brightness—3100 to 4900 footlamberts.

Results

The results of the tests are shown in Fig. 4 and Fig. 5. It was found that spot size was approximately proportional to distance. The increasing slope of the curves in Fig. 4 indicates that spot size would become infinite at some finite distance. However, the deviation from a linear function is actually very small and at greater distances, it would be expected that the curves would reverse and flatten out due to atmospheric absorption.

The effect of candlepower on spot size (Fig. 5) within the range studied was found to be essentially linear and relatively small—less than ten inches at any given distance. The curves for 2500 and 4300 feet are discontinuous at the low end of the range since the 25-watt lamps were not sufficiently visible to obtain readings. The 10,500-cp value at the upper end of the scale is probably the highest value that will be needed to meet most sign design requirements.

It was also found that while decreasing background sky brightness did tend to increase spot size, the effect was negligible compared to the variation with distance, until background sky brightness was less than 500 footlamberts. From this level down to black night sky, quite different effects occur.

Transition from Daytime to Night-Time Viewing

The skeleton letter "E" was set up and observed from 2500 feet over a range of background sky brightness from 450 ft-L to 12 ft-L with the results shown in Table III. The object was to determine when the candlepower must be reduced. Since a single step from rated voltage to one-half rated voltage is one logical solution, observations were made at these points.

TABLE III — Summary of Change in Appearance of Letter E as a Function of Time, Sky Brightness, Horizontal and Vertical Illumination.

Height — 8 Feet. 120-Volt, 75PAR/FL on 12-inch Spacing. Viewing Distance — 2500-ft Letter Facing West.

Time PM EDST	Sky Brightness ft-L	Illumination		Comments on Appearance			
		Horizontal ft-c	Vertical ft-c (on back of sign)	120 Volts		60 Volts	
				Legibility	Attraction Power	Legibility	Attraction Power
8:10	450			Excellent	Excellent	Not Good	None
8:20	270	70	43	Good — stroke width greater than space between bars	Excellent — Very Bright	Not Good	Very Poor
8:32	120	65	37	Still Good	Almost too bright	Good	Very poor— very thin orange lines
8:45	55	45	25	Still Good	Almost too bright	Good — Solid Lines	Poor — Orange Lines
8:52 Sunset	43	29	12	Fair — would be better with whole sign. Stroke quite heavy.	Extremely bright — Dazzling	Excellent	Would be good with whole sign — orange lines
8:57	26	16	8	Poor — extreme irradiation	Too Bright	Excellent	Would be good with whole sign — orange lines
9:06	12	7	2	Not Good	Brightness impossible — must be dimmed	Excellent	Good — losing orange appearance

From Table III it is seen that there is approximately a fifteen-minute period at sunset on a clear evening when the brightness of 75-watt PAR-38 floodlamps operated at 120 volts rapidly becomes excessive, and their brightness at half rated voltage is not yet sufficient for good attraction power. For conditions studied, the optimum time to switch from 120 to 60 volts is when the background brightness is about 55 footlamberts corresponding to 25 footcandles vertical illumination on the back of the sign. Decreasing voltage on an incandescent lamp, shifts the color of its light to the red end of the spectrum. Comparing this color with the color of daylight still present, accounts for the orange appearance noted. When daylight is gone, the lamps again appear more nearly "white."

The reduction of 120 volts to 60 volts in one step can be accomplished by connecting pairs of step-down supply transformers so that their primaries are either in multiple (rated volts) or series (half rated volts). The secondaries could also be similarly switched, but it is usually more economical to switch the high-voltage, low current side of the line.

Since there is a transition period in one-step dimming where the sign is either too bright or not bright enough for good attraction power, continuous dimming of the sign may be desirable. This could be done by operating the sign through a thyratron-controlled saturable reactor, with the thyratron regulated by a photoelectric cell. Such a system would provide smooth continuous reduction of candlepower so that legibility and attraction power would be maintained constantly.

Another way of providing night-time effectiveness would be to switch to an alternate set of lamps — 10 or 11S14, 25A19, 40A21 — mounted in the sign with the PAR lamps, and spaced according to previous sign design data.

Angle Viewing

Because typical sources have concentrated beams, the data are based on viewing the sign perpendicular to the plane of the letters. This would apply for a long-distance identification sign for a shopping center or service station, located along a highway, for example. However, a plant identification sign set some distance back from a highway or railroad is an example where effectiveness throughout a wide viewing angle would be desired.

Reference to Fig. 5 shows that the variation of spot size with candlepower is rather small in the range studied. For example, at 2500 feet it varies less than 10 per cent from 10,000 candlepower down to 5000 candlepower, or from 6000 cp to 3000 cp. Therefore, it can be said that about the same legibility (but not brightness) will be obtained throughout an angle within which the candlepower of the source does not vary more than 2 to 1. From Figs. 6A and 6B it can be seen that this is about 20 degrees for PAR spotlamps and about 35 degrees for PAR floodlamps.

When wider angles are involved, one of the following solutions apply:

1. Select wider-beam sources.
2. Place a spread lens over the lamp. Of course, this means a lower maximum candlepower.
3. Use two rows of lamps aimed at an angle to each

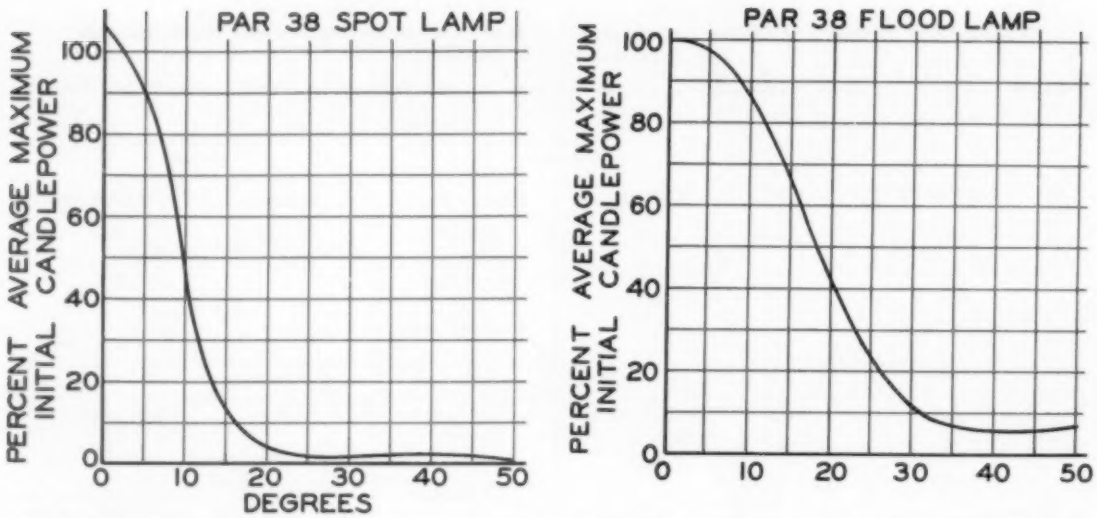

Figure 6. Candlepower distribution of PAR-38 spot and floodlamps in per cent of average maximum candlepower.

other. The angle should be chosen so that summation of candlepower is reasonably uniform throughout the viewing angle.

4. Reflecting equipment can be designed to fit the situation.

Example of Calculations

Design a sign to be effective at 2500 feet and to have smooth appearance of letter stroke at 1000 feet.

Step 1 Select the lowest candlepower lamp that has good attraction power at 2500 feet. (Table II) The 75PAR/FL is "excellent" on 6-inch spacing and "good" on 12 inches.

Step 2 Find the spot size of the lamp at 2500 feet. The candlepower of the 75PAR/FL is 1700 from Table I. From Fig. 4 the spot size is 23 inches.

Step 3 Find spot size at minimum viewing distance. From Fig. 4 this is 13 inches.

Step 4 Calculate minimum letter height (H) for daytime legibility at maximum viewing distance.

$$H = 2(SS) + 2(.0035D)$$
$$= 2 \times 23 + 2(.0035 \times 2500)$$
$$= 46 + 17.5 = 63.5$$

$2H$ = Letter Height for Advertising Effectiveness

$2 \times 63.5 = 127$ inches or about $10\frac{1}{2}$ feet.

Step 5 Calculate lamp spacing

Spacing = Half spot size at minimum viewing distance

= Half $\times$ 13 inches or about 6 inches.

Observation of the letter "E" indicates that this design will be effective during the day at 120 volts, over the indicated viewing range.

Conclusion

It has been shown that when viewed from a distance under daytime conditions, the apparent size of a high-candlepower light source varies almost directly with the distance viewed, within the range studied. Spot size also varies with candlepower, but to a much lesser extent. Also, in contrast to factors influencing night-time spot sizes, observation indicated that background brightness and total sign candlepower have a negligible effect on daytime spot size.

More work remains to be done to develop a complete set of design data for the numerous conditions that exist in practice. The range of candlepower, distance, and background brightness needs to be expanded, and further study of transitional effects from day to night viewing is essential. In all of these, a greater number of observers should be used. However, the data and observations that have been presented should be useful in the design of daytime effective exposed lamp signs where conditions are within the range that was studied.

The author gratefully acknowledges the guidance and counsel of Messrs. C. M. Cutler and R. T. Dorsey and the assistance of Messrs. E. H. Baker, W. L. Lowell, and A. I. Schwartz.

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INSTALLATION AT STATE PONTIAC, 600 EAST GAY ST., WEST CHESTER, PA.

Lighting a Used Car Sales Lot

LIGHTING OBJECTIVE: To floodlight a used car sales lot to call attention to its location and merchandise and to provide illumination for seeing and selling.

GENERAL INFORMATION: The area of the lot which is utilized for selling used cars measures 80 by 80 feet.

INSTALLATION: Eighteen "Duo Service" floodlights (Benjamin Electric Manufacturing Co. catalog No. 5934), using 1500-watt PS-52 clear general service lamps, are mounted on top of 35-foot high poles, six floodlights per pole These poles are spaced 25 feet apart and are located along the highway edge of the lot. This arrangement provides 60 footcandles on the front row of cars.

Lighting designed by T. H. Gallagher, Lighting Engineer, Philadelphia Electric Co., 1015 Chestnut St., Philadelphia, Pa.

Lighting data submitted by George T. Anderson, Jr., Philadelphia Electric Co., 1015 Chestnut St., Philadelphia, Pa., as an illustration of good lighting practice and to aid in the design of similar installations.

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The Efficiency Of Electroluminescence

By WILLI LEHMANN

The luminous efficiency (lumens/watt) of electroluminescence of powdered phosphors excited by an alternating voltage is dependent on amplitude and on frequency of the exciting voltage. Increasing voltage causes first an increase of efficiency and then, for higher voltages, a decrease. The peak efficiency and the electroluminescent brightness are connected with each other by some simple laws, which are discussed. With constant voltage but variable frequency, the efficiency is nearly independent of frequency for some phosphors, but very dependent on frequency for other phosphors.

Foreword

There now are three methods of producing light from electrical energy. The familiar incandescent lamps which utilize the resistance of a high melting point metal such as tungsten. By this method light is produced as a result of the incandescence of a metal body. Vapor lamp and variations in which light is produced by an electrical discharge maintained through metallic or other gaseous vapors to produce luminescence. The popular line of fluorescent lamps utilizes the arc principle to produce light, but in addition advantage is taken of the enormous production of ultraviolet energy to activate materials known as phosphors. Flux from this source accounts not only for the major output of light from these lamps but also determines the color characteristics of the light. For instance, a special phosphor is used in mercury lamps to supplement the light output of the mercury arc but more particularly to introduce light into the red end of the spectrum so that objects viewed in the blend of light produced appear more natural and realistic.

These two principles of producing artificial light account for nearly all the controlled light sources used today. Sources employing these principles have been modified in an almost inconceivable number of variations to meet specific needs and applications. There are naturally practical limitations which even these adaptable sources cannot adequately fulfill. There now exists in our complicated economy ample need for a new and different light source. Such a source utilizing a principle which is new and startling appears to be on the threshold of development. It also gives promise of rivaling its predecessor in the field of unique and useful light applications.

The faint glow of light that Georges Destriau observed when he subjected a phosphor material to high voltage while contained between two electrodes, now known as the Destriau effect, was by all previous knowledge unexpected. It ranks with one of the great scientific discoveries of the age. The utilization of this effect to produce electroluminescent light has already been advanced to a stage to attract serious attention for several applications.

This newest potential light source has characteristics which have appeal for applications in which space is an important consideration, as well as applications requiring an easily attainable range of brightness or color variations.

The development of this newest principle towards a practical efficient light source can only be described as remarkable. Starting from a glow that could be discernible only in a darkened room, there are in existence today experimental sources that reach one half the efficiency of a household incandescent lamp and brightnesses approaching those of fluorescent lamps as shown in Fig. 1. What may be more important, there do not appear to be any serious obstacles to further improvement nor yet has any definite ceiling to improvement been indicated as so clearly exists in the two classes of light source now in use.

This new light source, like vapor sources, will require auxiliary equipment for operation. At the moment this equipment is not readily available, nor in forms that are adaptable for general use, but as was true with vapor lamps, there are no unsurmountable obstacles to the development of such equipment. Fortunately the remarkable advance

A paper presented at the National Technical Conference of the Illuminating Engineering Society, September 17-21, 1956, Boston, Mass. AUTHOR: Lamp Division, Westinghouse Electric Corp., Bloomfield, N. J.

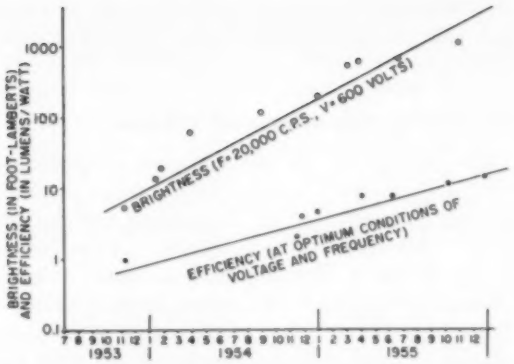
BRIGHTNESS (IN FOOT-LAMBERTS) AND EFFICIENCY (IN LUMENS/WATT)
1000
100
10
1
0.1
BRIGHTNESS (F=20,000 C.P.S., V=600 VOLTS)
EFFICIENCY (AT OPTIMUM CONDITIONS OF VOLTAGE AND FREQUENCY)
7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1953
1954
1955

Figure 1. Progress in improvement of electroluminescent brightness and efficiency.
Brightness: phosphor in castor-oil cells.
Voltage: 600 volts rms.
Frequency: 20 kcps.
Efficiency: peak efficiency of the phosphor itself.
Voltage: about 300 volts rms.
Frequency: 500 cps.

made in the development of transistors may hold much promise in the future commercialization of this newest light source.

The development of electroluminescent light source itself involves a number of related research problems. For instance, the phosphors used are not those that give best results in conventional light sources but constitute an entirely new family of these materials. These alone have supported and will continue to demand an extensive research program quite apart from the assembly of the cells. Again the method of incorporation of the phosphors in a suitable matrix as well as almost every detail of the cell assembly have required a coordinated and well planned research and development program which rivals any activity of this nature heretofore put forth. The importance of light to our overall present and future economy, in advancing the frontiers of civilization, welfare and convenience, dictates not only the continuation of the remarkable record of development of conventional light sources, but in addition it dictates that the success already attained, which in effect constitutes the unveiling of a new light source, electroluminescence, not only be continued but stepped up in all essential details to a position commensurate with its potential in the lighting field of the future.

Physical principles that are fully understood usually can be adequate described in terms of simple language. Conversely many useful principles cannot be so easily resolved and their explanation sometimes requires rather involved mathematical treatment. That to some extent is true of the Destriau effect and its application to produce a light source. Every effort will be made, however, to make the presentation interesting and objective.

Luminous Efficiency

The topic of this paper is the luminous efficiency (lumens/watt) of electroluminescence of powdered crystal phosphors embedded in an insulating medium and excited by an alternating electric field (Destriau Effect). Very little information on efficiency and its dependence on voltage, frequency, type of phosphor, etc., has been published,[1-7] although these questions are eminently important for practical applications of electroluminescence.

The efficiency measurements reported here have been made on electroluminescent phosphors of the zinc-sulfide type, mainly activated with copper, and excited with sinusoidal voltages of various amplitudes and frequencies. The measurements have been made only at room temperature. For experimental purpose, the phosphor powders were embedded in castor oil in a cell consisting essentially of a back electrode of aluminum and a front electrode of conducting glass (Fig. 2). The distance between the two electrodes was about 80 microns, the ratio of phosphor to oil in the cell was 20:80 by volume. The emission of the phosphor layer in this cell obeys very approximately the cosine law, *i.e.*, its brightness is practically independent of the direction of radiation. Under this circumstance, the number of lumens emitted by one square foot of cell area numerically equals the brightness measured in footlamberts, so that the luminous flux of a particular cell can easily be deduced from a simple brightness measurement.

An electroluminescent cell behaves electrically as a non-ideal capacitor having a certain electrical phase angle ϕ between the current going through it and the applied voltage. The wattage electrically absorbed by this cell is given by

$$W = 2\pi f V^2 C \cos\phi \qquad (1)$$

with f as the applied frequency, V as the applied voltage, and C as the electrical capacitance of the cell. The absorbed wattage was determined by

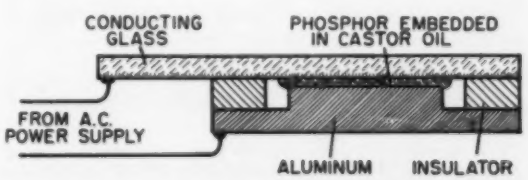

Figure 2. Electroluminescent cell used for measurements.

using this equation and measuring C and ϕ, a method which is much more accurate than a direct measurement of W with a wattmeter due to the wide range of frequencies employed. Details of the arrangement used to measure the light intensity L, the capacitance C, and the phase angle ϕ have been described in a previous publication.[8]

Generally we have to distinguish between at least two kinds of luminous efficiency of electroluminescence, both measured in lumens/watt:

a) The efficiency of the entire electroluminescent cell, taking into account the dielectric losses in the phosphor-embedding medium and the light absorption in the phosphor itself (reabsorption) and in both electrodes of the cell.
b) The efficiency of the phosphor itself.

The overall-efficiency of a complete electroluminescent cell depends, of course, on many constructional details of the cell. For this reason, only the efficiency of the phosphor itself will be considered in this paper. It can be determined by some separate measurements the details of which will not be discussed here.

Power Absorption and Efficiency

In equation (1) the term $C\cos\phi$ is the imaginary part of C'' of the complex capacity of the complete cell, $\vec{C} = C' + iC''$ (where $i = (-1)^{1/2}$). The power absorption in the phosphor only can be described by a similar expression:

$$W = a f V^2 k'' \qquad (2)$$

where C'' has been replaced by the imaginary part k'' of the complex dielectric factor,* $\vec{k} = k' + ik''$ of the phosphor and where all other constants are included in the constant a. The dependence of k on V and f has been determined and published already,[8] the result is

$$k'' = k_o'' + a \text{ function of } (L/f). \qquad (3)$$

Except for the region of very highest voltages, the function of (L/f) has been found to be simply proportional to $(L/f)^{1/2}$, so that equation (3) becomes

$$k'' = k_o'' + b\,(L/f)^{1/2} \qquad (4)$$

where k_o'' may be slightly dependent on the frequency f but is independent of the voltage V, while b is a constant independent of both f and V. Combination of equations (2) and (4) gives an efficiency of

$$\eta = \frac{L}{W} = \frac{(L/f)}{a V^2 [k_o'' + b\,(L/f)^{1/2}]} \qquad (5)$$

This equation holds very well in almost all cases and will be compared here with experimental results.

The Voltage Dependence of Efficiency

The dependence of the luminous efficiency of electroluminescence on the applied voltage is qualitatively the same for all frequencies and for all types of phosphors yet investigated. An example is shown in Fig. 3. The brightness increases with increasing voltage up to the highest applied voltages. The efficiency is very low in the region of low voltages due to the very low brightness L. With increasing applied voltage, the efficiency increases due to the rapidly increasing brightness, goes through a maximum at moderate voltages, and decreases again for still higher voltages up to the breakdown limit of the cell. This behavior of electroluminescence is quite in contrast to that of other light sources since high brightness and high efficiency do not appear simultaneously. This behavior also facilitates somewhat practical application of electroluminescence since it is not necessary, in order to obtain highest efficiency, to increase the voltage to just below the breakdown limit; rather the voltage should be about half the breakdown voltage.

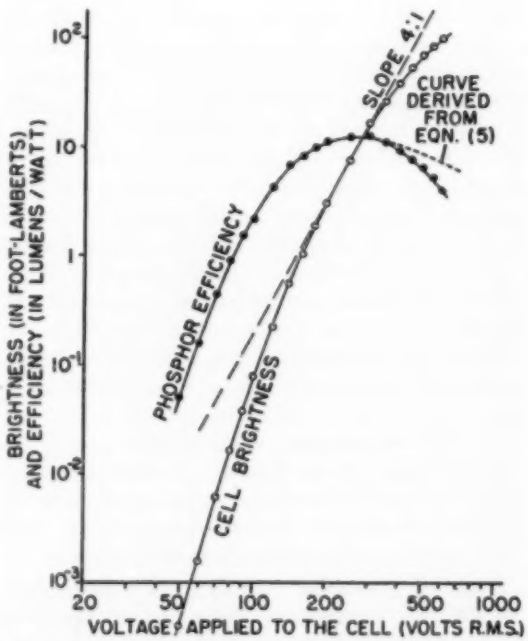

Figure 3. Typical voltage dependence of brightness and efficiency of electroluminescence.
Phosphor: green-emitting ZnS-Cu, Cl.
Frequency: 50 cps.

*It is somewhat misleading to speak about a "dielectric constant" in connection with electroluminescence. The designation "dielectric factor" is preferred here since it is, in the case of electroluminescent phosphors, dependent on field strength and on frequency.

The experimental points for the efficiency in Fig. 3 are very well represented by equation (5), as shown by the dotted line, except in the region of highest voltages. This agreement permits the derivation of an interesting conclusion concerning the value of the voltage corresponding to maximum efficiency. In the voltage range near this point $k_e'' \propto b\,(L/f)^{1/2}$ for practically all good electroluminescent phosphors so that equation (5) reduces to

$$\eta = c\,\frac{L^{1/2}}{V^2} \tag{6}$$

with $c = 1/(a\,b\,f^{1/2}) = \text{const}$. Thus, as V increases η increases as long as $L^{1/2}$ increases faster than V^2. The peak efficiency should appear near that voltage where $L^{1/2}$ increases just proportionally to V^2 or, in other words, where L increases proportionally to V^4. Although this conclusion is, due to the simplifications which have been introduced, only an approximation, it is confirmed by the measurements, as shown also in Fig. 3 where the peak efficiency appears near that voltage where the dependence $L(V)$ can be described by $L \propto V^4$. This observation has been made on all phosphors yet investigated in this respect and at all frequencies (between 20 and about 10,000 c.p.s.).

Still another conclusion may be derived from equation (6) for the region of moderate voltages and the peak efficiency. A comparison of two different electroluminescent phosphors excited with the same voltage and frequency under similar conditions gives the relation:

$$\frac{\eta_1}{\eta_2} = \frac{c_1}{c_2}\left(\frac{L_1}{L_2}\right)^{1/2} \tag{7}$$

where the index numbers 1 and 2 refer to the two phosphors to be compared. It is a matter of experience that the constant c is largely independent of the phosphor as long as phosphor type (*e.g.*, ZnS-Cu) and emission color remain constant. A comparison of brightness and efficiency of two nearly similar phosphors, therefore, gives the relation

$$\frac{\eta_1}{\eta_2} = \left(\frac{L_1}{L_2}\right)^{1/2} \tag{8}$$

In simple words, equation (8) expresses the fact that with an increasing number of free electrons in the phosphor the emission intensity L increases proportionally to n^2 but the wattage W only proportionally to n, so that the efficiency (the ratio L/W) also increases proportionally to n, *i.e.*, proportional to $L^{1/2}$. Equation (8) permits estimation of the peak efficiency of new phosphor samples by a simple brightness measurement and comparison with another sample whose brightness and efficiency under similar excitation conditions are known. Such a comparison is shown in Table I. Although equation (8) has been derived only for the neighborhood of the peak efficiency, the agreement between estimated and measured efficiency for phosphor sample 2 of the table is very good even for higher and lower applied voltages.

TABLE I — Comparison of Brightness and Efficiency for Two Slightly Different Phosphors under Similar Excitation Conditions. (Castor-oil cell, frequency 500 cps.)

V	Brightness (footlamberts)			Efficiency (lumens/watt)		
volts rms	L_1	L_2	$(L_1/L_2)^{1/2}$	η_1	η_2 estimated	η_2 measured
100	0.018	0.038	1.45	1.6	2.3	2.1
120	0.053	0.11	1.44	2.8	4.0	4.1
140	0.12	0.27	1.50	4.3	6.5	6.7
160	0.25	0.50	1.41	5.6	7.9	7.9
180	0.41	0.90	1.48	6.5	9.6	9.5
200	0.65	1.48	1.51	7.2	10.9	10.6
250	1.62	3.6	1.49	8.0	11.8	11.8
300	3.1	7.9	1.59	7.9	12.5	12.6
350	5.3	12.5	1.53	7.3	11.2	10.4
400	8.2	18.4	1.50	6.4	9.6	8.7
450	11.4	26	1.50	5.2	7.8	7.5
500	15.2	34	1.48	4.0	5.9	6.2
550	19.8	40	1.42	3.0	4.3	5.0
600	24	48	1.41	2.2	3.1	4.6

The Frequency Dependence of Efficiency

In case of a constant voltage V, the efficiency is, according to equation (5), only dependent on the ratio L/f and, since for many phosphors the brightness L increases roughly proportional to the frequency f, the efficiency in these cases is almost independent of the applied frequency f. A typical example of a phosphor showing this independence is given in Fig. 4. However, there are several exceptions to this rule. Two of the most important of these are the following:

a) Some electroluminescent phosphors, especially those with very high activator concentrations, are characterized by strong thermal quenching of their luminescence. Experiment shows that thermal quenching

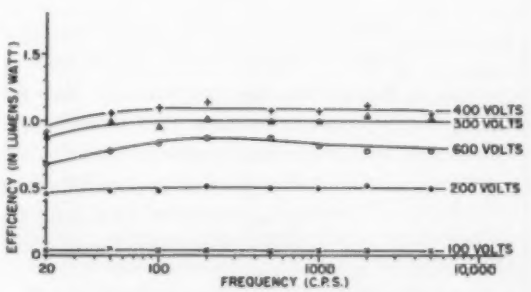

Figure 4. Frequency dependence of efficiency. Phosphor: blue-emitting ZnS-Cu.

of electroluminescence is independent of the applied voltage but is dependent on the frequency; the strongest thermal quenching of the electroluminescence occurs at the lowest frequencies.[9] The practical result is that in the range of thermal quenching the electroluminescent brightness does not increase nearly linearly with frequency but at a much more rapid rate; increases as rapid as $L \propto f^2$ have actually been measured. Hence, the efficiency generally increases with frequency in that range where thermal quenching occurs, *i.e.*, mainly at low frequencies.

b) Practically all electroluminescent phosphors show an increase of L less than proportional to f in the region of very high frequencies (in the order of some 10^4 c.p.s. or more). This effect is dependent on the phosphor type, on the voltage, and probably also on other influences and it causes, according to equation (5) a decreasing efficiency in the region of very high frequencies.

Both of these two deviations are shown in Fig. 5 on an otherwise reasonably good phosphor. The degree of these deviations varies, of course, from phosphor to phosphor. Their practical result is, for almost all phosphors, a distinct efficiency peak not only at a certain voltage but also at a certain frequency.

Outlook

Equations (5) to (8) reflect a very happy situation regarding the development of electroluminescence to the status of a practical light source, since high brightness and high efficiency go together and do not exclude each other. It would be disastrous for future applications of electroluminescence if high brightness and high efficiency were mutually exclusive. However, the efficiency of electroluminescence is still too low to be applied for general illumination purposes although rapid progress has been made in the recent years. This progress, as far as obtained in our laboratory, was shown in Fig. 1. It can be seen that two years of intensive work caused an improvement in brightness of a factor of 200 and in efficiency of a factor of 15. To what extent further improvements are possible cannot yet, of course, be said, but the future looks encouraging.

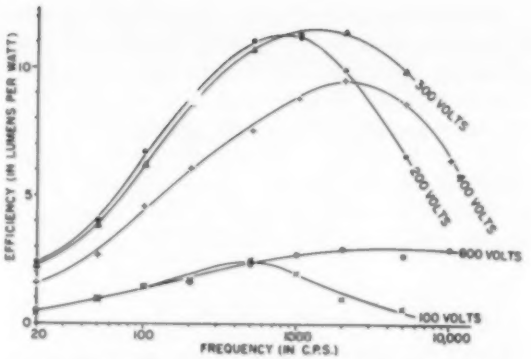

Figure 5. Frequency dependence of efficiency. Phosphor: green-emitting Zn S-Cu, Cl.

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Glow Starter Design and Fluorescent Lamp Life

By W. H. LAKE

FLUORESCENT LAMP ballast circuits and lamp performance thereon have been the subject of many competent articles in the past.[1,2,3,4] The two-lamp "lead/lag" ballast, a familiar component on the commercial scene, has received particular attention because of lamp performance problems stemming from the leading power factor (lead) circuit. Short lamp life on this circuit has been the most persistent of these problems. No one factor may be singled out as the primary cause since lamp characteristics, ballast voltage and current characteristics, and starter characteristics all contribute significantly to the problem. In early lead circuits, low preheat current was found to cause much of the short lamp life and a "compensator" was added which seemed to have corrected the difficulty.[2] Design and processing advances over the intervening years have greatly improved lamp quality and lamp starting ability. As a result, lead circuit lamps often start without cathode preheating and the short life problem has again become acute.

In the past little attention has been given to starter characteristics as a factor in producing the short lead life.[3] In fact, ballast voltage waveform* distortion caused by starters seems to have been entirely neglected in considering starting of preheat type lamps. This paper intends to show that such distortion will cause lamps to start without cathode preheating at one extreme and may be controlled so as to compensate for shortcomings of other circuit components at the other extreme. It will be shown that proper design of the glow switch can minimize the short life problem.

Normal Preheat Start and Instant Starting Defined

Preheat type (switch-start) lamps require a suitable period of cathode heating before starting voltage should be applied. Industry specifications require one second of cathode heating at 0.55 amperes for the standard 40-watt T12 fluorescent lamp. At the end of this period, the cathode has attained a temperature sufficient to supply ample current carriers to support the discharge without undue damage to the cathode. When the cathode does not reach a high enough temperature and the lamp still starts, high local electric fields result. Physical loss of and surface contamination of emission material caused by such starts are a primary factor in shortening lamp life.

Two factors control the final cathode temperature for a given coated cathode: these are the magnitude and the duration of the preheating current. If we consider only those ballasts which meet present industry standards, the magnitude of the preheating current will be sufficient provided that the duration is one second or more. The duration of cathode preheating is primarily a function of starter characteristics, and in the absence of "instant starting" may be easily controlled by starter design. When cathodes receive no preheating before the lamp is started, it has received an "instant start." Here, the cathode is completely cold when the lamp starts, and the maximum loss and contamination of emission material results.[1,4]

Present industry-wide methods for testing starters do not detect the high degree of instant starting prevalent in leading power factor circuits. Investigation has shown that lamps do not readily instant start unless they have been burned a minimum of around 100 hours. Repeated instant starts without several hours burning between starts will virtually eliminate instant starting. Unfortunately, if such lamps are returned to normal operation, (several hours of operation between starts) the ability to instant start is rapidly recovered. Beside the above, lamp instant starting characteristics are found to depend on the length of the intermediate burning period, the length of off time between burning and starting, the total number of instant starts sustained, and total burning hours.

It is obvious then that a test which uses lamps as a primary criterion must be very carefully controlled and test conditions carefully selected. If

*Note that all reference to "ballast voltage waveforms" shall denote unaltered open circuit characteristics unless otherwise specified.

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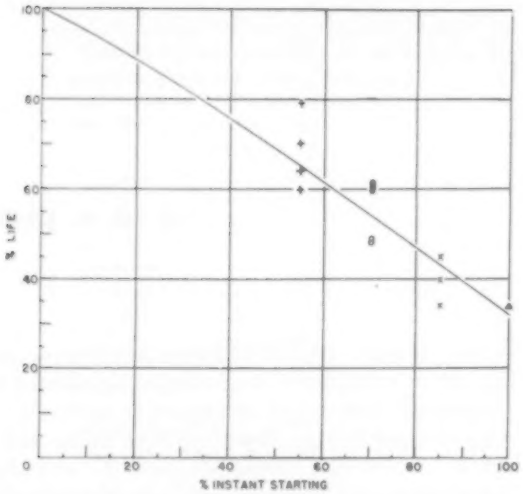

Figure 1. Effect of instant starting on life of 40-watt switch start lamps.

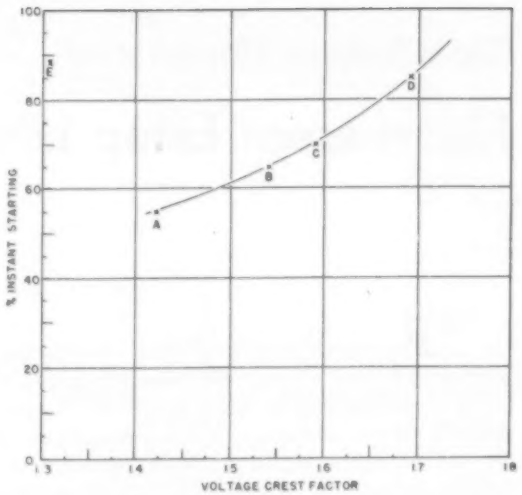

Figure 2. Voltage crest factor and instant starting in 40-watt "lead" circuits.

properly done, consistent and reproducible data result which closely evaluate the effects of instant starting in field installations. The tests described herein have been carefully controlled and it is believed that lamp conditions have been selected which best reflect field service operation.

A curve relating instant starting under these criteria to lead lamp life as actually experienced under field service conditions can be derived as shown in Fig. 1. The one hundred per cent instant starting point is the result of operating switch start lamps in instant start circuits. The zero per cent point represents average lag lamp life under normal operating conditions. The other points are typical of commercial ballasts and starters in general use. This curve indicates the magnitude of the short life problem and the need for corrective measures.

Instant Starting As a Function of the Ballast

Until recently the ballast has been generally blamed for causing instant starting. As a consequence, most attempts to meet the problem have involved changes in ballast characteristics. Measurements on ballast effects have been taken almost exclusively in lead circuits with the starter omitted. A high percentage of lamps will instant start under these conditions with many commercially available ballasts manufactured in the past. Ballast B, Table I, was designed to minimize this type of instant starting, but does not represent a unique combination of ballast characteristics, since many other choices are available. In particular, the reduction of lamp end-to-fixture voltage by about 50 per cent, accomplished by changing the autotransformer primary circuit ground point from the bottom tap to the center tap, will virtually eliminate instant starting in starterless lead circuits. When a glow starter is included in the circuit, however, a very high degree of instant starting is imposed on that produced by the ballast in starterless circuits. The result with Ballast B, is to increase instant starting from about two per cent to nearly 65 per cent. The extent of the increase for other ballasts depends to a large degree on their specific characteristics.

The three major ballast characteristics involved in instant starting in circuits using starters are voltage crest factor, rms voltage, and lamp end-to-fixture voltage. Fig. 2 shows the effect of voltage crest factor on instant starting. The individual ballast characteristics are given in Table I.

Ballast E shows an abrupt increase in instant starting for a low value of crest factor (1.31). It is believed that this sudden change is due to the

TABLE I — Characteristics of Ballasts of Fig. 2.

Ballast	Voltage at 118 Prim. Volts RMS	Peak	Crest Factor at 118 Prim. Volts	rms Voltage to Fixture	% Instant Starting with Starter
A	208	295	1.42	208	55%
B	205	316	1.54	205	65%
C	208	332	1.59	208	70%
D	210	355	1.69	210	85%
E	217	282	1.31	217	88%

TABLE II — Effect of rms Voltage Variations and Lamp End-to-Fixture Voltage on Instant Starting.

Ballast B

Primary Volts	RMS Secondary	Peak Secondary	Crest Factor	RMS Voltage to Fixture	Instant Starting
106	188	290	1.54	188	10%
110.5	195	301	1.54	195	65%
118.0	207	322	1.55	207	85%
125.0	219	340	1.55	219	80%
118.0	207	322	1.55	118	70%

peculiar characteristics of the ballast which are necessary to reduce the crest factor below that of the input waveform (1.41).

The effect of rms voltage does not show a simple regular relationship. There is an abrupt transition from very little instant starting to a high degree of instant starting, and the transition point is not necessarily the same for ballasts of different waveform. Table II shows this transition for a particular ballast. The reasons for these sudden changes are not as yet fully understood.

If the secondary voltage rating of the ballast is dropped to a value just below the transition level, instant starting can be eliminated. However, it is not sufficient simply to eliminate instant starting.

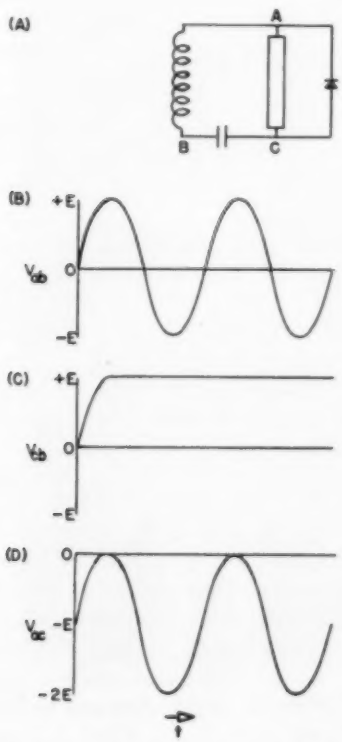

Figure 3. Voltage doubling in the "lead" circuit.

Reliable starting must be provided under all conditions which lamps may reasonably encounter. This level would be too low to provide reliable starting at low temperatures, high humidity, and/or low line voltage. On the other hand, when high line voltage conditions are present, the transition level would be exceeded and instant starting would return. It would be difficult to achieve a satisfactory compromise between these two extremes.

Lamp end-to-fixture voltage does not substantially alter the data as given above even when this voltage is reduced by about 50 per cent.

These data are valid for FS4 and FS40 type starters which are representative of commercially available glow type starters. It is evident that no simple change of ballast characteristics can provide an adequate solution to the short lead lamp life problem.

Instant Starting and Starter Effects

When voltage is applied to the starting circuit, the glow switch breaks down and glows. The heat generated by the discharge causes the bimetal to close. The closing period ordinarily takes from 0.1 sec. to about 0.5 sec. It is during this time that instant starting occurs. Thus the lamp does not "see" the open circuit voltage waveform, but one modified by the glow characteristics of the glow switch. The form of the distortion has perhaps the greatest effect of any factor on instant starting.

The simplest form of distortion which causes instant starting is rectification in the glow switch discharge, *i.e.*, the switch carries more current in one direction than the other. Unequal electrode areas and/or dissimilar electrode work functions characterize rectifying type glow switches. To understand what rectification does, consider a typical lead circuit such as shown in Fig. 3a. The glow switch has been replaced by a perfect rectifier, for simplicity. Point B is taken as the voltage reference point and Fig. 3b shows the voltage at A with respect to B (normal open circuit voltage). When the voltage at A is going positive, the glow switch (rectifier) passes current and a charge builds up on capacitor C, such that the voltage, C to B, becomes E_o (peak voltage of the ballast). Assuming there is no current flow through the lamp, and that the glow switch blocks the flow of current perfectly in the back direction, plate C will always be maintained at the peak value of the charging voltage. (Fig. 3c.)

The voltage across the lamp is found from:

$$V_{AB} = V_{AC} + V_{CB}$$

or $V_{AC} = V_{AB} - V_{CB}$; where $V_{AB} = E_o f(\theta,t)$

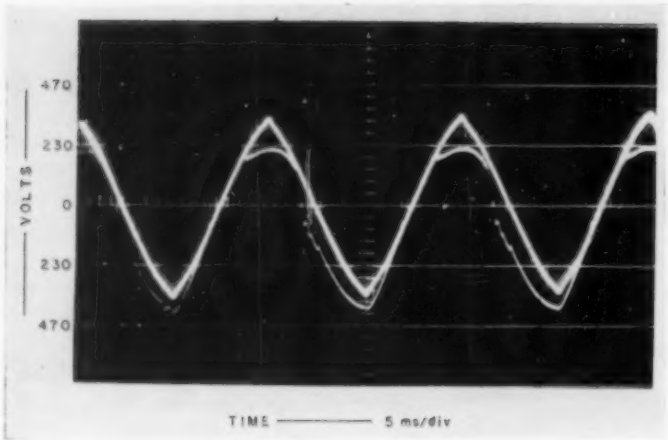

Figure 4. Typical glow voltage waveform —rectification only (FS40). Heavy trace —open circuit voltage; light trace—voltage in lamp position as modified by glow-switch.

Assuming a perfect sine waveform $f(\theta,t) = \sin \omega t$, then, when plate C is fully charged, $V_{CB} = E_o$
and $V_{AC} = E_o \sin \omega t - E_o \ (\omega = 2\pi f)$
and when

$$t = 3\pi/2n = n\,270^\circ \ (n = 1,2,3,4,\text{-------}x),$$
$$\sin \omega t = -1$$
and $V_{AC} = -2E_o$

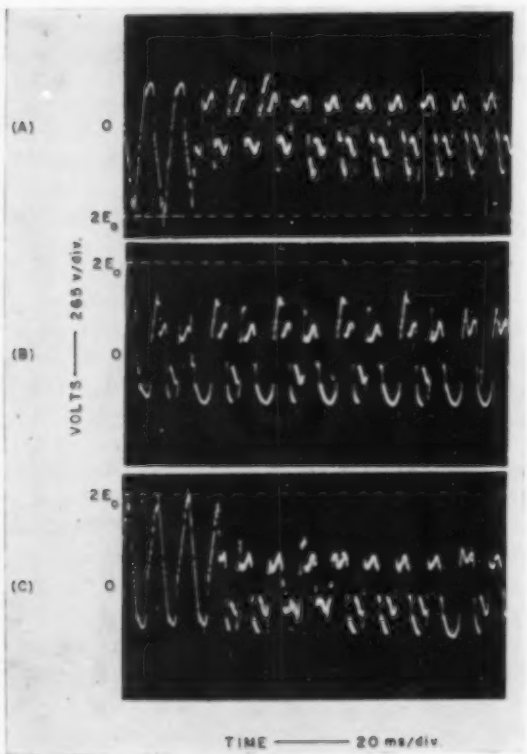

Figure 5. Typical instant starts — rectification and oscillation (FS40).

That is to say, with point, C, as a reference voltage point (Fig. 3d), the voltage applied to the lamp will attain twice the normal peak voltage available from the ballast every cycle. Such a voltage would exceed the peak voltage of a 40-watt instant start ballast.

In Fig. 4, the waveform of the glow voltage is compared to the open circuit waveform of the ballast. In the positive direction the glow switch carries a large current and the voltage characteristic falls far short of the open circuit waveform. In the negative direction, the glow switch carries very little current and the residual charge (at plate C, as described above adds to the open circuit voltage. Here the leakage current carried by the glow switch rectifier causes much lower peaks than the $2E_o$ to be expected from the perfectly rectified condition. The peaks due to rectification seldom exceed 150 per cent of the normal open circuit peak. However, the rms voltage is substantially increased along with the peak voltage and is in itself sufficient to cause a very high degree of instant starting.

An additional factor, an oscillatory characteristic, can send these peaks well over $2E_o$ or double the normal peak voltage. This factor is inherent in most glow switch constructions and in particular is typical of FS4 and 40 type glow switches. Fig. 5 (a, b, c) shows typical instant starts as caused by this type glow switch.

Removal of the rectifying characteristics is not sufficient to substantially alter the instant starting picture. The oscillatory characteristic mentioned above can cause voltage peaks nearly as high as the combined effects of rectification and oscillation. A non-rectifying glow starter which has oscillatory characteristics causes as much or more instant

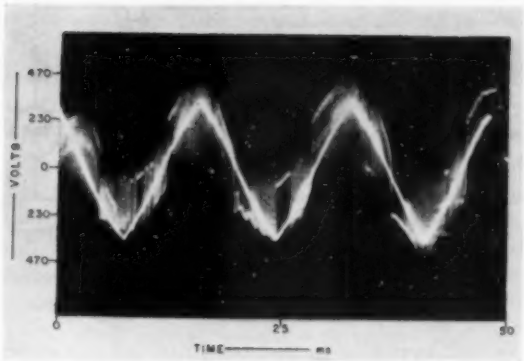

Figure 6. Typical glow voltage waveform —non-rectifying, oscillatory. (FS40).

starting since its peaks occur every half cycle instead of only once per cycle as with rectifying starters. The oscillations are caused by sudden current "bursts" through the glow switch during the glow period. The L-C-R system of the starting circuit opposes these sudden changes resulting in high frequency oscillations which are to a great degree self-maintaining. Fig. 6 compares the distortion caused by this starter to the open circuit waveform. The open circuit voltage waveform (heavy trace) has been superimposed on the high frequency oscillations of the glow voltage waveform. Fig. 7 (a, b, c) shows typical instant starts caused by a commercially available non-rectifying type FS40 glow starter (Symmetrical Bimetal).

Requirements for Instant Starting Suppression

Obviously, the glow starter is extremely important in instant starting the lead circuit lamp. In order to reduce instant starting significantly the starter must not produce voltage peaks in the waveform impressed across the lamp during starting which exceed the peak of the ballast voltage.

A glow starter then shall not rectify and shall not exhibit oscillatory phenomena. The former requirement is easily obtained by using electrodes of equal "effective" area and similar work function. The latter effect may be minimized by the proper choice of filling gas and ionizing agents. Such a starter would limit instant starting to that caused directly by the ballast. Actually the waveform distortion caused by such a glow starter will improve on the ballast voltage waveform (Fig. 8). The rms voltage has not been changed significantly, but the peak voltage has been sharply reduced. The

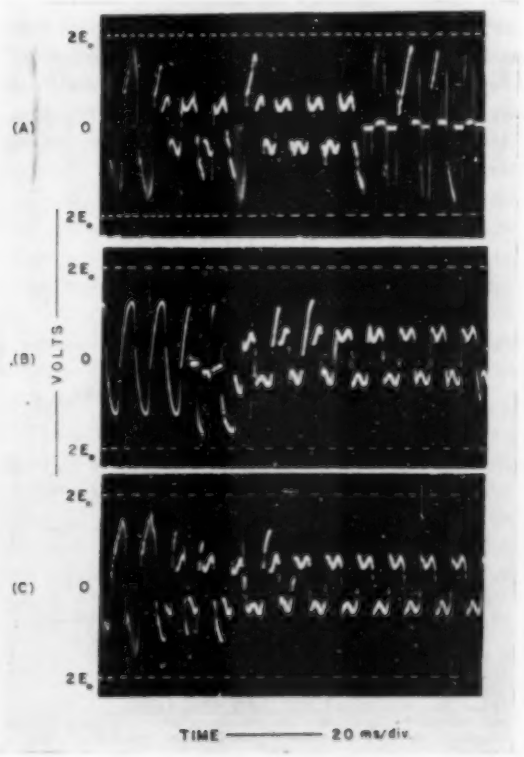

Figure 7. Typical instant starts — non-rectifying, oscillatory (FS40).

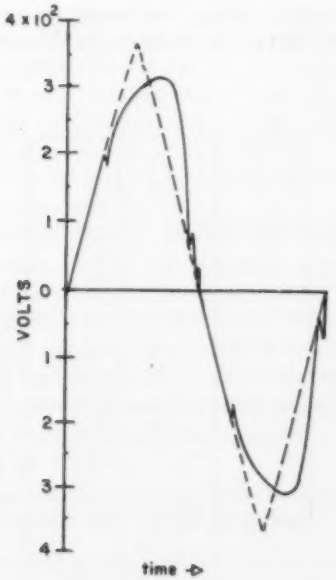

Figure 8. Glow voltage waveform — non-rectifying, non-oscillatory. Open circuit voltage—Peak 365, rms 208, crest factor 1.79; Glow voltage—Peak 313, rms 205, crest factor 1.53.

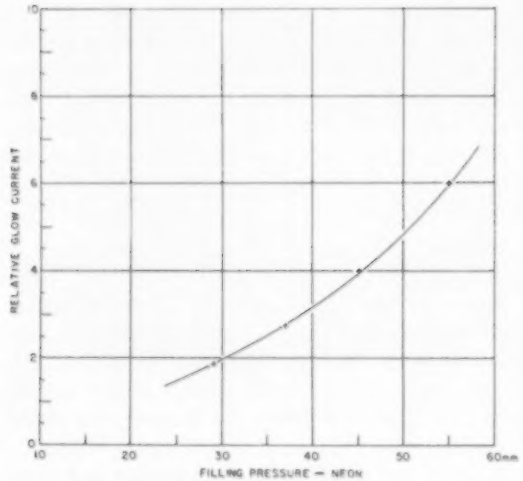

Figure 9. Current carrying capacity dependence on filling gas pressure (neon-filled glow switch).

effect is easily explained in terms of inductive (ballast) opposition to changes in circulating current (glow current). Reduced peak voltage means reduced crest factor which according to Fig. 2 causes less instant starting. With the above in mind, it is possible to ensure good lead lamp life in future installations with properly designed ballasts and the modified glow-switch.

Unfortunately, this provides little consolation to most owners of existing installations. For these users the glow voltage waveform even with the "improved" starter, is sufficient to cause up to 30

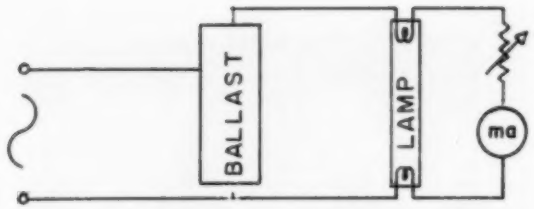

Figure 10. Test circuit for current required to suppress instant starting.

per cent reduction in lead lamp life. At this stage in the discussion three alternatives are available:

1. Use specially designed "hard starting" lamps.
2. Replace the ballasts and use the type of starter described above.
3. Use thermal starters.

Hard starting lamps inevitably result in poor starting under adverse conditions, *i.e.*, low temperature, high humidity, and/or low line voltage. The margin of safety between unreliable starting and instant starting is too critical to expect more than a poor compromise. Reballasting an installation is an obvious extreme and is just as obviously undesirable in terms of cost. Thermal starters will stop instant starting, but experience has shown that the fragility and cost of thermal starters compared to glow starters make them much less desirable. Therefore, for those who are concerned with existing installations, a further step is required, that is, a glow starter which will minimize instant starting in existing ballast circuits.

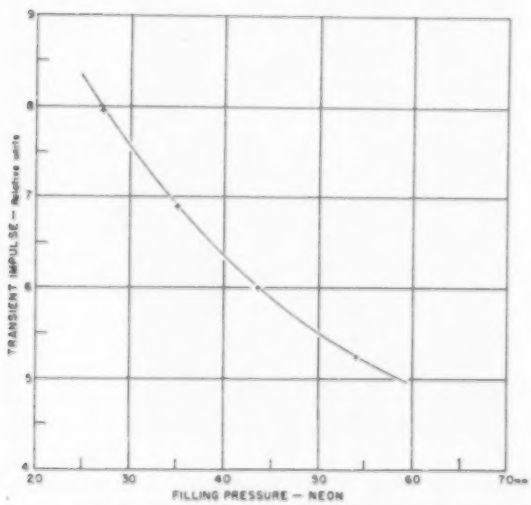

Figure 11. Starting transient dependence on filling gas pressure (neon-primary gas).

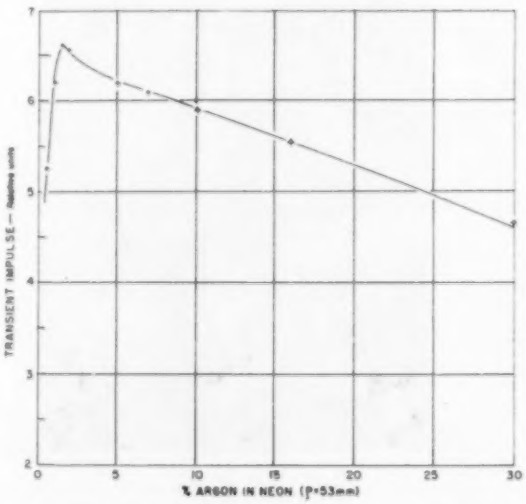

Figure 12. Starting transient and per cent of argon "impurity gas" in neon.

We must, of course, begin with a glow switch, such as described above, which neither rectifies nor shows extreme oscillatory characteristics. In order to eliminate instant starting the peak voltage which the lamp sees must be reduced sufficiently to compensate for excessive peak voltage of the ballast. The glow voltage peak may be readily controlled by means of the filling gas pressure. Increasing the filling gas pressure increases the current carrying capacity (Fig. 9) which in turn reduces the peak glow voltage.

The glow current required to reduce the peak voltage sufficiently to stop instant starting can be easily found. Using a circuit, such as Fig. 10, it is found that about 200 ma is adequate. Other switch characteristics must be considered, however, before a reliable starter can be offered to the industry.

High current carrying capacity can definitely impair the switch's ability to start lamps. A transient voltage impulse, which determines the ability of the switch to start lamps[5] occurs when the switch bimetal snaps open. This transient is a function of the current-carrying characteristic (gas pressure) according to Fig. 11, which confirms data, taken with slightly different methods, of F. H. Rixton.[6] At the pressures required for instant starting suppression, the transient is too low to start lamps reliably for most switch constructions.

Fortunately, additional control of the transient impulse is afforded by use of impurities in the primary filling gas. Mixtures of neon and argon have the curious effect on the transient impulse shown in Fig. 12. It is possible to choose a mixture within the proper breakdown voltage limits which has an entirely adequate transient impulse and still maintain the all important current carrying characteristics. Other switch parameters have decided effects on switch operation and instant starting. However, all these effects can be readily controlled to achieve the proper peak lowering characteristics and need not be discussed in this paper.

The glow voltage characteristics of Fig. 13 are those of a switch which provides instant starting suppression and reliable starting for most existing types of leading power factor ballasts. Note that the peak glow voltage is relatively independent of the ballast peak characteristic. The dramatic improvement in life is best shown by comparing the average instant starting for the non-instant starting glow starter (FS400) and the present standard glow starter (FS40) as shown in Table III.

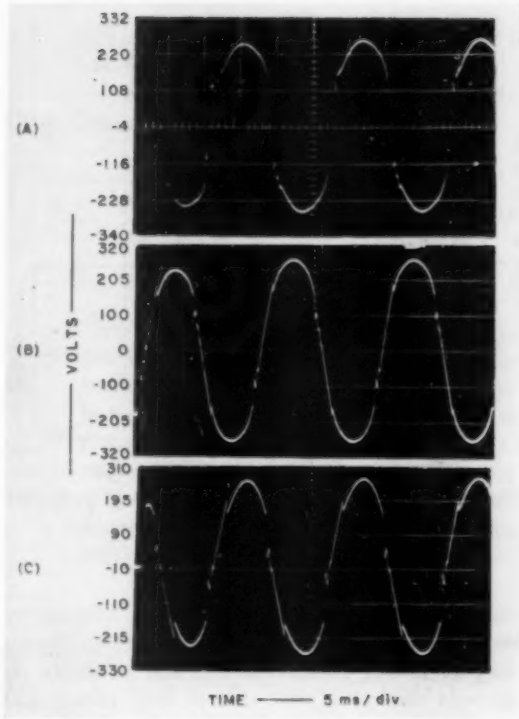

Figure 13. Glow Voltage waveform — FS400.

Ballast open circuit voltage	Glow Voltage
(a) rms 208, crest factor 1.79	Peak 266
(b) rms 218, crest factor 1.34	Peak 267
(c) rms 207, crest factor 1.55	Peak 268

These tests represent a composite figure of production tests of FS40 and FS400 starters for 10 months of 1954 and 1955.

An important feature of this equalizing of lead and lag lamp lives is the elimination, to a large degree, of the "early" failures now experienced in many existing group replacement installations. For example, with existing FS4 and 40 starters the failures of lead circuit lamps are often 30 per cent or more at 5000 hours when operated at three hours per start, but are usually less than three per cent with the FS400.

TABLE III.

Starter	Primary Volts	RMS Secondary	Peak Secondary	RMS Voltage to Fixture	Instant Starting
FS40	118	207	326	207	77%
FS400	118	207	326	207	6%

Testing Starters for Instant Starting

As described above, industry wide methods for testing starters do not expose instant starting. General use of starters which reduce or eliminate instant starting probably will not come about until a simple method for testing the effect of starters

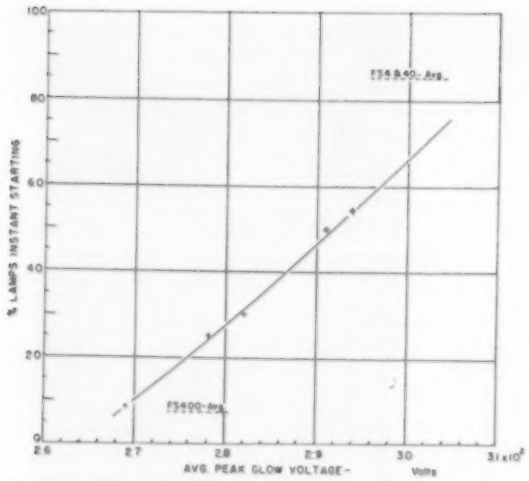

Figure 14. Instant starting as a function of peak glow voltage.

can be devised which may be readily adopted by the industry. The methods as described herein used for testing instant starting and its effects, do not lend themselves well to large scale testing and are by no means simple. However, the investigation reported in this paper suggested a method for testing the instant starting characteristics of starters which does not require the use of lamps.

The peak value of voltage in the lamp position of a lead circuit during the glow period before switch closure, shows a definite relationship to instant starting as shown in Fig. 14. The characteristic of Fig. 14 is of a ballast which in itself causes a high degree of instant starting. Other ballasts show a similar relationship, but with reduced slope. To achieve 90 per cent of average lag lamp life in lead circuits (Fig. 1) instant starting must be reduced below about 10 per cent. From Fig. 14, the average peak glow voltage of a glow starter should then not exceed something like 270-275 volts for existing ballast types.

It is not difficult to design a device which could measure the peak voltage developed across the starter during the initial glow period. Such an instrument would allow for large scale testing of glow type starters for instant starting ability without the disadvantages inherent in a program using lamps as the primary criteria.

Summary

Instant starting in the lead circuit of the two-lamp "lead/lag" ballast in conjunction with standard FS4 or FS40 starters causes short lamp life. When lamp life in such circuits is compared to the average lamp life in the lag circuit, we find that at best the average lead lamp attains about 70 to 80 per cent of the average lag lamp life. In the extreme, this figure can be as low as 30 per cent. It is found that the starter glow characteristic is a primary factor in causing short lead lamp life.

Glow starters allow a wide latitude for design with regard to the glow voltage characteristic. With many designs the glow voltage exceeds the normal peak ballast voltage. In this case the starter becomes the primary source of instant starting and will override ballast characteristics which in themselves are entirely satisfactory. Such starters are represented by FS4 and FS40 starters of present design. At the other extreme it is possible to design a glow starter which will alter the ballast voltage characteristics so that instant starting is virtually eliminated even for ballasts which in themselves can cause a very high degree of instant starting. Such a starter is represented by the FS-400 starter, which on most existing types of commercially available ballasts will assure that the average lead lamp life will attain 90 per cent of the average lag lamp life, and greatly reduce the number of failures experienced before 5000 hours.

Some relatively simple criteria may be applied to the glow characteristics of a starter in order to determine if it will cause instant starting. Starters which meet these criteria will normally provide an average lead lamp life which will be better than ninety per cent of the normal lag lamp life of a given ballast.

Acknowledgments

I wish to express my appreciation for the assistance and encouragement given me by D. D. Hinman of the Large Lamp Engineering Section in the preparation of this paper.

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Sector Flux:

A Useful Concept for Practical Lighting Design

By H. D. EINHORN

"Sector Flux" is a concept which facilitates the calculation of direct illumination from long linear sources such as rows of fluorescent luminaires. After defining sector flux, its practical application is demonstrated by examples. Methods of estimating sector flux values for common luminaire types are discussed, and correction rules for applying this infinite line source quantity to finite sources are given.

LONG LINES of fluorescent luminaires have become increasingly popular in recent years for the lighting of factories, large stores, public buildings, show windows, etc.

A relatively new concept — "Sector Flux" — makes the prediction of direct light received from these long linear sources extremely simple and rapid. It was investigated some five years ago[1] and has been used continually since then for practical illumination design. It has proved itself a useful special tool, surprisingly simple to handle once its range of applicability is understood.

The practical electrical and illuminating engineer who favours a bold approach to design without unnecessary complications may well ask: Why a new concept? The answer is twofold: New applications warrant new methods; and a new tool is worth acquiring if it saves time afterwards and is able to do jobs which cannot be done easily without it.

The job which the "Sector Flux" concept can do is the assessment of direct light from long line sources. It is essentially a method for point-by-point calculations, similar to the use of the intensity concept for point sources.

It is rather less important than the latter in the photometric laboratory, but probably at least as useful for practical design, since infinite line source calculations are relatively simple.

Definition and Formulae

It is a well known fact that the illumination from a long linear source does not follow an inverse square law as in the case of point sources, but obeys an inverse first power law, $E = k/R$, where k is a constant and R the distance of the object surface from the source axis. The constant k would depend on the source and will vary for different directions, and the "Sector Flux" concept is introduced to describe this constant for any particular type of source.

Like intensity it is a directional quantity, and for any line source a polar curve, normal to the axis, can be drawn in terms of sector fluxes.

If we call the sector flux J, the illumination E, at distance R from the source, on a surface parallel to the source axis but tilted from the direction of incidence by an angle β (see Fig. 1), then

$$E = \frac{J}{R} \cos \beta \qquad (1)$$

The unit for the sector flux J is *lumen per foot per radian* (lm/f.r.), if the distances are in feet and the illumination in footcandles.

The most common practical case is that of horizontally mounted lamps lighting different points on a horizontal or vertical plane (Figs. 2 and 3). If H, Z, R are in feet and defined as shown in the figures, the same equation applies in both cases:

$$E = \frac{JH}{H^2 + Z^2} \qquad (2)$$

This illumination value, although strictly applying only to an infinite source, will in practice be obtained at points not too near the end of a row of lights. The interpretation of "not too near" will be discussed in the section on End Effect. Some examples will first be given to demonstrate the simplicity and some potentialities of the method. Other examples, *e.g.* industrial local lighting and stack lighting, can be found in reference 1.

Example I: Local Lighting for Vertical Surfaces

When lighting blackboards, pictures, sign boards, lettering, etc., the positioning of the luminaires

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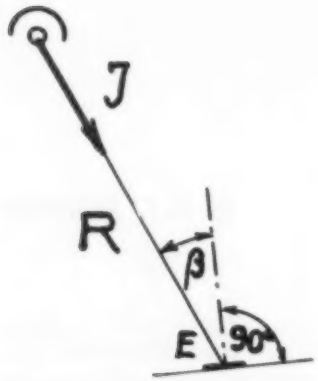

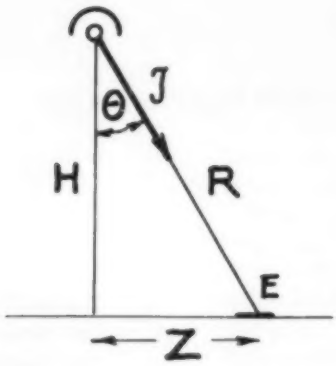

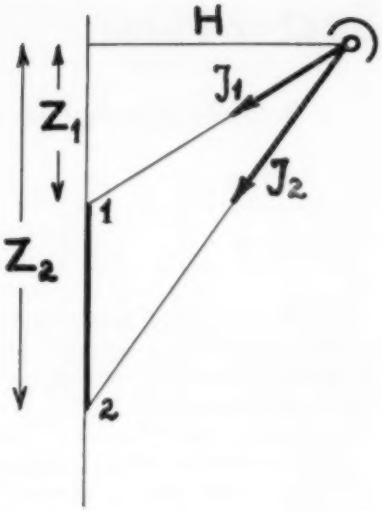

Figure 1 (left). General layout.

Figure 2 (center). Illumination on horizontal plane.

Figure 3 (right). Illumination on vertical plane (example: picture lighting).

presents a problem which is not always fully understood; a common mistake is to place the light sources too close to the object plane, resulting in uneven illumination.

Calculation by conventional methods would either be elaborate or unreliable. A sector flux calculation shows quickly where best to place the units, or conversely what polar curve to aim at when selecting or designing the luminaires.

(i) *Choice of position*

Referring to Fig. 3, one can easily prove[1] that for maximum illumination at point 2 for given Z_2, we must make $H_{opt} = Z_2$, *i.e.* aim at 45 degrees incidence of light at the critical object point.

(ii) *Calculation of Illumination*

Let us take as example the lighting of exhibition walls by single 4-ft 40-watt reflectors, mounted end-to-end.

Assume we make $H = 5'$, $Z_2 = 7'$, $Z_1 = 3'$, and have a reflector yielding sector flux values of $J_1 = 130$ and $J_2 = 180$.

$$\text{Then at point 1}: E_1 = \frac{130 \times 5}{25 + 9} = 19 \text{ ft-c}$$

$$\text{and at point 2}: E_2 = \frac{180 \times 5}{25 + 49} = 12 \text{ ft-c}$$

(iii) If it is desired to improve uniformity, the units could be placed further away; alternatively it may be possible to redesign or tilt the reflector to obtain a different ratio J_2/J_1. For either purpose a few simple sector flux calculations could yield useful information.

Example II: Uniformity Check

The decision how far luminaires can be spaced without resulting in disagreeable variations of illumination is sometimes based on published recommendations,[4] more often on experience, sometimes

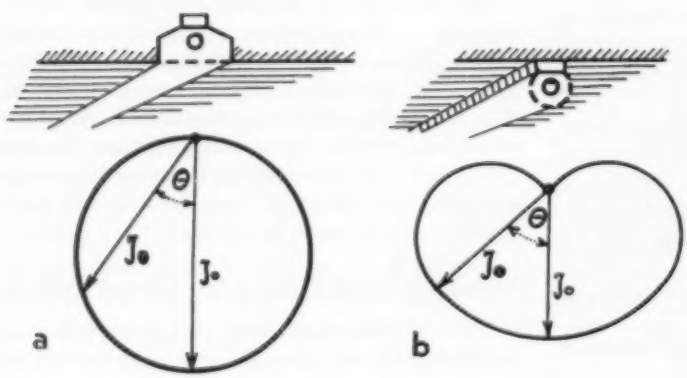

Figure 4a. Diffusing plane panel.

Figure 4b. Diffusing semi-cylinder.

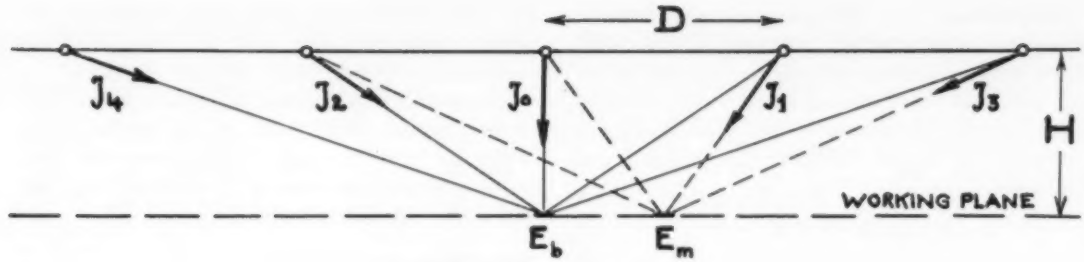

Figure 5. Uniformity check.

on general rough rules, such as: "spacing not to exceed 1.5 height above the working plane."

In the case of linear layouts, the sector flux concept allows very easy calculation of the illumination distribution due to direct light, provided the normal polar curve* is known. Reflected light will introduce a "safety factor" or can be assessed by the inter-reflection or similar methods.[4,5] Studies of this kind lead to a fuller appreciation of the function of different luminaire designs.

The following example will show this:

A large area, *e.g.* a department store, is to be lighted by a linear arrangement of fluorescent lamps. Two different kinds of luminaires (Fig. 4) will be compared at different spacings.

The illumination below the luminaires E_b and midway between rows E_m will be calculated (see Fig. 5) yielding the uniformity factor E_m/E_b for the central working area.

Introducing $\delta = D/2H$, one can easily derive from equation (2) that

$$E_b = \frac{J_o}{H}\left(1 + \frac{2a_2}{1+4\delta^2} + \frac{2a_4}{1+16\delta^2}\right) \qquad (3)$$

$$E_m = \frac{J_o}{H}\left(\frac{2a_1}{1+\delta^2} + \frac{2a_3}{1+9\delta^2}\right) \qquad (4)$$

In these equations a_1, a_2, a_3 - - - are taken from the normal polar curves, namely $a_\theta = J_\theta/J_o = I_\theta/I_o$ (see Fig. 4).

Note that the polar curves do *not* have to be in terms of sector flux, they may be in terms of intensities as usually published, in fact the units of the polar vectors need not be known at all provided the curve is drawn to scale.

Assuming a spacing of $D/H = 1.5$; *i.e.* $\delta = 0.75$, we obtain

$$E_b = J_o/H \times (1 + 0.62a_2 + 0.20a_4) \qquad (3a)$$

$$E_m = J_o/H \times (1.28a_1 + 0.33a_3) \qquad (4a)$$

From the polar curve of the diffusing panel (Fig. 4a): $a_1 = 0.80$, $a_2 = 0.55$, $a_3 = 0.41$, $a_4 = 0.3$.

Hence $E_b = 1.40\,J_o/H$, $E_m = 1.16J_o/H$,

and $E_m/E_b = 0.83$.

The semi-cylinder, Fig. 4b, with its rather broader polar curve, has intensity (or sector flux) ratios of $a_1 = 1.0$, $a_2 = 0.99$, $a_3 = 0.96$ and $a_4 = 0.93$. By a similar calculation, we obtain $E_b = 1.80$, $E_m = 1.60$, and $E_m/E_b = 0.89$.

This shows that projecting diffusing luminaires, such as semi-cylindrical, cylindrical, or box type, as well as plain bare lamp channels could be spaced wider apart with little harm. Even for the rather wide spacing $D/H = 2$ *i.e.* $\delta = 1$, E_m/E_b becomes only 0.79 for the projecting luminaires which might be accepted, but 0.64 for the flush panels which would surely be excessive.

End Effect

In theory the sector flux concept is only applicable to infinite sources, in practice all sources are finite. Sector flux calculations are therefore approximative in character, but so are most illumination calculations.

Experience shows that equations (1) and (2) as they stand are accurate enough for most practical purposes. In some applications, however, a check, or, better still, a correlation for the end effect may be desired, and in any case we like to know the limitations of the method.

One statement can be made immediately, on symmetry considerations: the illumination below the end of a very long source, is *one-half* of the illumination far away from the end, provided the source is symmetrical (in the sense that the axial polar curve of a single luminaire is symmetrical). This is usually the case.

The transition from this half value to the full value far away from ends depends on the axial polar curve. A full treatment of this function has been given previously:[1] for practical purposes Fig. 6 should suffice.

*"Normal P.C.," as used here means: in a plane perpendicular to the lamp axis; "Axial P.C." means: in a plane containing the lamp axis.

The full line in Fig. 6 applies to bare fluorescent lamps, and with practical accuracy to most luminaires with or without reflector or diffusing covering, provided there are no cross louvers or prismatic control. The Δ-scale in Fig. 6 can be used as correction for results obtained by equations 1 and 2, namely

$$E = (J/R)\,(1 - \Delta)\cos\beta \qquad (5)$$

Note, that this correction is less than 5 per cent, if $X > 1.25\,R$, *i.e.* for distances from the lamp end greater than 1.25 object distance. In cases where *both* ends must be considered, two corrections are obtained and simply added. ($\Delta = \Delta_1 + \Delta_2$.)

For cross louvers this correction function would lie somewhere in the shaded area in Fig. 6, and the actual luminaire design must be known for more accurate prediction, which is rarely required.

The practical conclusion is worth noting: in all linear layouts, those parts of the working area which lie below the ends of lamp rows are liable to be underlit, particularly if the reflection from end walls is not very high.

Gaps Between Luminaires

The sector flux concept is *not* restricted to a perfectly continuous source. The effect of lamp holders and dark lamp ends is as a rule quite negligible. Even if lamps are spaced several feet apart the method can be applied with practical accuracy,

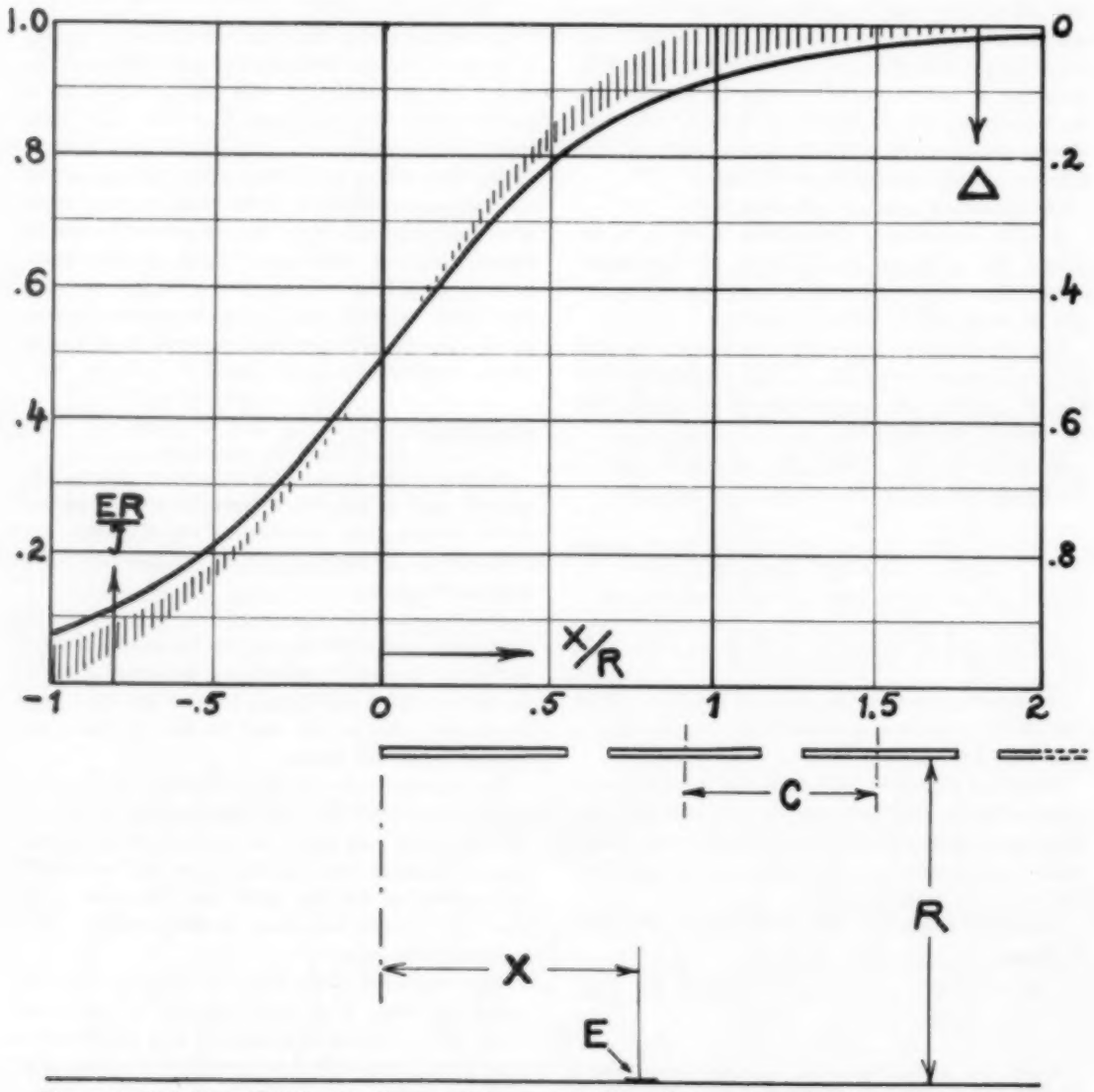

Figure 6. End-effect. Full line for fluorescent lamps and plain reflectors. Shaded region for cross louvers.

TABLE I — Bare Lamp Sector Flux Values.

Spacing (C)	Sector Flux (J) / Lamp Flux (F)	Lamp Type (Example)	Lamp Flux (F) (Assumed)	Sector Flux (J) (Derived)
4′	0.04	40-w 4500° White	2250 lm.	90 lm/f.r.
4′	0.04	40-w WW de Luxe	1500 lm.	60 lm/f.r.
5′4″	0.03	80-w 4500° White	4200 lm.	125 lm/f.r.
5′4″	0.03	80-w WW de Luxe	2800 lm.	85 lm/f.r.
8′	0.02	75-w Slimline	4500 lm.	90 lm/f.r.
8′	0.02	45-w Cold Cathode	2250 lm.	45 lm/f.r.

Corrections:
(a) For two adjacent lamps, double J-values in directions where lamps do not screen each other. For more lamps, multiply by 3, 4, etc.
(b) For diffusing reflectors, multiply by a suitable factor, say between 1.8 and 2.5 for vertical direction.
(c) For louvers, deduct a suitable amount, say 10-20 per cent for vertical direction.

provided the distance from the source to the objects illuminated is larger than the pitch C between lamp centers, *i.e.* if $R > C$ (Fig. 6).

It is important, of course, to realize that the sector flux value itself is inversely proportional to the pitch for any luminaire type used. If therefore the sector flux for four-foot luminaires is J when mounted end-to-end, the reduced value J_C for pitch C is $J_C = 4J/C$.

This leads to the question: How do we know the sector flux value for any particular application?

Assessing Sector Flux Values

Sector flux values have not so far been published by luminaire manufacturers. This could hardly be expected considering the relative novelty of the concept, although measurement on a single luminaire can be made with inexpensive apparatus.[2] One has at present therefore to estimate the J values or calculate them from other data known.

(i) A simple estimating method consists of assessing the J value for bare lamps and then multiplying it by suitable factors to allow for reflectors or louvers.

For bare lamps which can be considered as uniform sources[1]

$$J = F/2\pi C$$

where F is the output of each lamp, C the mounting pitch. (See Fig. 6.)

A few typical examples are given in Table I.

For reflectors these values should be multiplied by suitable factors which can be estimated from experience with candela values, since reflectors affect I and J in practically the same way. For louvers a percentage deduction has to be made, which in the vertical direction is rather less than the percentage lumen loss of the luminaire due to the louvers.

(ii) Another way of estimating J is to base it on intensity values if the latter are known, *e.g.* if a normal polar curve in terms of candelas is available. The ratio of J/I_o has been calculated for three fundamental cases[1] and measured for a number of practical luminaires.[3] Here I_o is the intensity per unit length, *i.e.* the intensity of one luminaire divided by the mounting pitch C. Table II gives some representative values.

TABLE II — Ratio of Sector Flux/Intensity p. Ft.

Type of Source	J/I_o
Perfectly diffusing source	$\pi/2 = 1.57$
Matt reflectors	1.5 - 1.6
Bare fluorescent lamps	1.47
Flush 040 Perspex	1.44
Combined louvered and diffusing	1.3 - 1.4
Louvered luminaire	1.1 - 1.3

Note: I_o = luminaire intensity/C

(iii) An accurate determination of J can be made if a normal polar curve and the *net* light output F_n of the luminaire are known. In this case

$$J_\theta = \frac{I_\theta}{I_{av}} \frac{F_n}{2\pi C} \qquad (6)$$

where I_θ is the intensity vector in the direction of interest θ,
I_{av} is the average value over 360 degrees of all polar vectors.*
F_n is, of course, the product of lamp flux × light output ratio while C as before is the mounting pitch.

As an example let us consider the flush diffusing panel shown in Fig. 4a.

Assume it has a light output ratio of 54 per cent and contains 40-watt lamps of 2250 lm mounted end-to-end, at 4′1″ pitch. Hence the average sector flux

$$J_{av} = F_n/2\pi C = .54 \times 2250/2\pi 4.1 = 47 \text{ lm/f.r.}$$

The mean of all vectors in the polar curve can be determined as 0.32 of the maximum in a vertically downward direction. Hence $J_o = 47/.32 = 147$ lm/f.r. which establishes the scale of the polar curve. Assuming further that H is 9 ft, then $E_m = 1.16 \times 147/9 = 19$ ft-c.

Similarly for the semi-cylindrical luminaire with a light output ratio of 64 per cent, we get $J_o = 56/.59 = 95$ lm/f.r. and $E_m = 1.60 \times 95/9 = 17$ ft-c. Since this unit has an indirect component of nearly 20 per cent, reflected light would bring the illumination more or less up to the value obtained for the plane panels.

*This is readily obtained from the polar curve, since the simple average is meant; methods such as Rousseau's diagram used for rotational polar solids do not apply here.

Limitations of Method

The method has in the past been successfully applied for estimating the illumination on surfaces parallel to the source, in particular on a horizontal working area with horizontal rows of luminaires. If surfaces are tilted towards the end of the source, calculation becomes more intricate and the result depends on the axial polar curve.[1] In particular for calculating illumination on a vertical surface, normal to the lamp axis, *e.g.* an end wall, other methods are probably at least as convenient.[7] For vertical or inclined surfaces parallel to the source axis, however, the sector flux concept applies readily.

The main other limitation is the ratio of length of source/distance to object. End effects discussed become too large to allow easy approximation unless the source length is greater than the object distance.

For larger distances finite line source calculations are required[6,7] which are not nearly as simple as the sector flux method. For still larger distances, say greater than two lamp lengths, the source can be treated as a point source, if necessary with a correction.[6]

Conclusions

This article attempts to explain the application of the sector flux concept to practical lighting design. Its use should facilitate the prediction of illumination in cases where more complex methods of calculation had to be used before, which meant in practice that guessing often took the place of calculating. It is hoped, therefore, that rational design will be fostered by its introduction.

A final word to those concerned with teaching illuminating engineering: the restriction of elementary courses to point source calculations often leads to misconceptions about the universality of the inverse square law. Line source studies form an antidote against its thoughtless application, and are simplified by the sector flux concept as teaching experience has shown.

Appendix.

Comparison with McPhail's "Los" Function.

McPhail[7] has proposed a method of calculating direct illumination from linear sources, using two functions called "los" and "sol."

One can show that "los" is related to the J/I_o ratio (see Table II) and the function ER/J depicted in Fig. 6 as follows:

For infinite source: $J/I_o = 2 \text{ los } \infty$.

(The factor 2 enters because "los" is defined for a semi-infinite source.)

For a finite source:

$ER = J(1 - \Delta_1 - \Delta_2) = I_o(\text{los } X_1/R + \text{los } X_2/R)$

Here Δ_1 and Δ_2 are to be taken from Fig. 6.

The curve in Fig. 6 and the los function are thus related:

$ER/J = (1 - \Delta) = 0.5\ (1 + \text{los } X/R \,/\, \text{los } \infty)$

Similarly, for object surfaces perpendicular to the source, the curves E_pR/J in figure 8 of Reference 1, correspond to "sol" functions, thus

$$E_pR/J = 0.5 \text{ sol } X/R \,/\, \text{los } \infty$$

The relative merits of the two methods can only be judged on grounds of convenience. While quantitative prediction is possible by both, the speed and ease of obtaining results in practice differ according to the job to be done.

In the author's opinion each method is specially suited to a different but overlapping range of applications.

The sector flux concept is simpler and easier to handle in cases where the end-effect can be neglected, *e.g.* for rough estimates, and generally if $X > 1.2\,R$, in which case the "los" curve is practically a horizontal line. Uncorrected sector flux calculations have the advantage of not being dependant on the knowledge of axial polar curves.

If on the other hand accurate prediction of illumination values near the end of the source is desired, in the case of special luminaires with unusual axial polar curves, *e.g.* due to prismatic luminance control, "los" functions based on measurement are most suitable. So are "sol" functions for calculating the illumination on surfaces which are not parallel with the sources.

There remains a fair range of applications where both methods can be used with about equal convenience, *e.g.* for the accurate prediction of illumination in the case of finite sources built up of luminaires, employing enamel reflectors or diffusing media for light control. The choice of method will then be a matter of taste or of luminaire data available.

The sector flux concept has, however, a fundamental importance which transcends taste and convenience, namely as the property of an infinite line source analogous to the intensity of a point source.

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Watch for November I.E. . . . .

. . . which will feature the winners in the National contest for My Most Interesting Lighting Job.

Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of E. H. Salter, has prepared these answers to questions concerning light sources. Readers are invited to submit similar questions of general interest to be considered for publication. Questions should be sent to the Committee in care of Society headquarters.

Can rapid-start fluorescent lamps be successfully operated on switch-start ballasts?

Forty-watt rapid-start lamps will give good life performance in luminaires using ballasts designed for switch-start (pre-heat) lamps. However, glow-switch starters should be used. Thermal-switch starters may cause early end discoloration of the lamps.

What is the difference in lumen rating between the deluxe and standard white fluorescent lamps?

The "deluxe" lamps produce more red light than the "standard" lamps in order to provide a more pleasing color rendition for some applications. Due to the lower luminosity of red light there is a resultant reduction in efficiency for the "deluxe" lamps. The "deluxe" lamps will have approximately 30 per cent less initial lumens than the corresponding "standard" lamps.

Why do deluxe cool white fluorescent lamps of different manufacturers appear to differ in color?

The color appearance of various fluorescent lamps long has been covered by Federal Specifications. These specifications require that lamps of a given color (for example, cool white of a color temperature of 4500K) meet the color requirement within certain definite tolerances. These tolerances are approximately ±20 minimum perceptible color differences (MPCD). Lamps of all reputable manufacturers are maintained carefully within these color limits. However, lamps that are well within specifications may appear slightly different in color if viewed side by side.

In the case of deluxe colors, each manufacturer is primarily interested in the color rendition of his lamps rather than their precise color appearance. As a result of this emphasis on color rendition, there is probably a greater variation in color appearance of deluxe lamps, although these lamps too are maintained within the tolerances permitted by Federal Specifications for the standard colors.

How much drop in the supply voltage will cause fluorescent lamps to black out?

Different lamps and ballast combinations will give different results, but the following will serve as approximate supply voltages that will cause 40-watt fluorescent lamps to be extinguished.

Switch-start ballasts	
Lead circuit	60 volts
Lag circuit	85 volts
Rapid-start, series ballast	95 volts
Instant-start ballast	
Lead circuit	35 volts
Lag circuit	45 volts
Instant-start, series ballast	60 volts

It should be realized that the extinction voltage which is given here is not the same as the ignition voltage and that, in general, lamps will not relight if only extinction voltages are applied. Continued operation at voltages approaching these limits may drastically curtail lamp life.

How successful is the "rejuvenating" process as applied to fluorescent lamps?

With a normal failed fluorescent lamp, the cathode emission material is completely dissipated from at least one cathode. This material is deposited on the inner bulb-wall surface and the Committee is not aware of any method of returning the material to the cathode in order to bring back useful life to the lamp.

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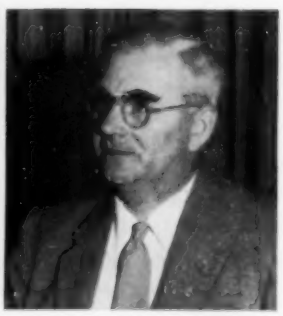

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Chairman, Bluenose Chapter

J. P. R. Cristel
Chairman, Montreal Section

James H. Rylance
Chairman, Ottawa Chapter

G. E. Davidson
Chairman, Toronto Section

D. J. Bourdon
Chairman, Winnipeg Chapter

(Photographs of John H. Mills, Hamilton Ontario Chapter Chairman; G. Dubeau, Quebec Chapter Chairman, and the chairman of the Maritime Chapter not available in time for publication.)

EAST CENTRAL REGION

Nelson C. Warner, Regional Vice-President and member of the I.E.S. Council

H. V. Oerting
Chairman, Capital Section

Charles A. Oerkvitz
Chairman, Eastern Pennsylvania Section

C. Edward Sparrow, Jr.
Chairman, Maryland Section

J. P. Boyden
Chairman, Pittsburgh

Dean N. Jenks
Chairman, Virginia Chapter

(Photograph of W. R. MacKinney, Chairman of the Philadelphia Section, not available in time for publication.)

GREAT LAKES REGION

R. M. Taylor, Regional Vice-President and member of the I.E.S. Council

Edwin L. Moyer
Chairman, Central New York Section

Merle E. Keck
Chairman, Cleveland Section

D. R. Hughes, Jr.
Chairman, Miami Valley Chapter

Harry R. Robbins
Chairman, Michigan Section

Robert Colgan
Chairman, Northwestern Ohio Section

V. G. McClusky
Chairman, Ohio Valley Section

R. Bruce Thompson
Chairman, Rochester Section

W. Dale Crites
Chairman, Western Michigan Section

Byron F. Lyth, Jr.
Chairman, Western New York Section

INTER-MOUNTAIN REGION

J. D. Whitnell, Regional Vice-President and member of the I.E.S. Council

Leonard J. Carlon
Chairman, Rocky Mountain Section

Robert F. Even
Chairman, Southern Colorado Chapter

Wayne F. Mulcock
Chairman, Utah Section

(Photographs of John F. Gohring, Arizona Section Chairman, and Robert J. Uhl, New Mexico Chapter Chairman, not available in time for publication.)

NORTHEASTERN REGION

C. E. Waldron, Regional Vice-President and member of the I.E.S. Council

Merritt Horner
Chairman, Connecticut Section

C. M. Holden
Chairman, New England Section

G. G. Rae
Chairman, New York Section

Arthur C. Brodeur
Chairman, Yankee Chapter

(Photograph of C. D. Hollister, Chairman of the Eastern New York Section, not available in time for publication.)

MIDWESTERN REGION

Joseph A. Schneller, Regional Vice-President and member of the I.E.S. Council

Eric Church
Chairman, Chicago Section

Ford Bates
Chairman, Cornhusker Chapter

F. E. Miles
Chairman, Heart of America Section

Denton E. Hall
Chairman, Indiana Section

Gale L. Williams
Chairman, Iowa Section

William M. Lisch
Chairman, Milwaukee Section

Robert J. Welch
Chairman, St. Louis Section

A. A. Aronson
Chairman, Twin City Section

Kenneth Peterson
Chairman, Twin Ports Chapter

(Photograph of R. Weiman, Chairman of the Central Illinois Chapter, not available in time for publication.)

PACIFIC NORTHWEST REGION

Kenneth Reid, Regional Vice-President and member of the I.E.S. Council

D. S. Gordon
Chairman, British Columbia Section

Don Frost
Chairman, Chinook Chapter

George E. Romans
Chairman, Inland Empire Chapter

Dudley D. Moore
Chairman, Oregon Section

Howard C. Hall
Chairman, Puget Sound Section

A. S. Harris
Chairman, Vancouver Island Chapter

(Photograph of R. C. B. Jarvis, Chairman of the Edmonton Chapter, not available in time for publication.)

SOUTH PACIFIC COAST REGION

C. M. Thompson, Regional Vice-President and member of the I.E.S. Council

Guy De Leuze
Chairman, Golden Gate Section

G. A. Hochenauer
Chairman, Southern California Section

(Photographs of G. S. Kimball, San Diego Chapter Chairman; George Baker, San Jose Chapter Chairman, and the Chairman of the Mother Lode Chapter not available in time for publication.)

SOUTH CENTRAL REGION

George L. Morris, Regional Vice-President and member of the I.E.S. Council

W. J. Pettyjohn
Chairman, Alabama Section

Volney O. Riser
Chairman, Arkansas Chapter

H. F. Collins, Jr.
Chairman, Mid-South Chapter

Richard E. Cope
Chairman, Mississippi Chapter

S. Conrad Berdon
Chairman, New Orleans Section

Joe W. Fowler
Chairman, Tennessee Valley Section

SOUTHEASTERN REGION

J. Dixon Mitchell, Regional Vice-President and member of the I.E.S. Council

W. M. Pearson
Chairman, Georgia Section

R. Neal Campbell
Chairman, Palmetto Chapter

A. H. Bruning
Chairman, Suwannee River Chapter

A. L. Ducker, Jr.
Chairman, Tar Heel Section

(Photographs of George N. Jack, Florida Section Chairman, and J. V. Shellhorse, Southeast Floridn Chapter Chairman, not available in time for publication.)

SOUTHWESTERN REGION

John C. Felton, Jr., Regional Vice-President and member of the I.E.S. Council

Robert G. Turpin
Chairman, Alamo Chapter

Clifford Ham
Chairman, Ark-La-Tex Chapter

Charles E. Davis
Chairman, Central Oklahoma Chapter

F. Allen Whiteside
Chairman, Oil Capital Section

(Photograph of C. W. Grevelius, Chairman of the San Jacinto Section, not available in time for publication.)

Thomas J. Lynn
Chairman, Panhandle Chapter

John B. Deck, Jr.
Chairman, Southwestern Section

LIGHTING NEWS

Windows and Glass Exteriors — Topic of Building Conference

"Windows and Glass in the Exterior of Buildings" is the topic for a two-day research correlation Conference to be conducted by the Building Research Institute, November 14 and 15 at the United States Chamber of Commerce, Washington, D. C.

The purpose of the conference is to report on the newest and most interesting developments concerning the use of glass in the subject field and to correlate this information, to describe problems that exist in the use of windows and glass products and to propose solutions for these problems, and to identify research that needs to be done to achieve a better use of windows and glass in buildings. The conference is open to the public.

This will be the thirteenth research correlation conference conducted by the Building Research Institute or the Building Research Advisory Board. The Institute is a unit of the Division of Engineering and Industrial Research of the National Academy of Sciences-National Research Council, a private nonprofit organization chartered by Congress.

The program, and speakers, for the conference are as follows:

WEDNESDAY, NOVEMBER 14

First Session: Functions of the Building Environment

Principles of Daylighting Buildings—Professor J. W. Griffith, Southern Methodist University.
Design of Glass for Daylighting — Dr. R. A. Boyd, University of Michigan.
Research in Heat Gain and Loss — E. R. Kaiser, Director of Research, American Society of Heating and Air Conditioning Engineers Laboratories.
Design for the Control of Heat Gain and Loss — Alfred L. Jaros, Jr., Jaros, Baum & Bolles, New York City Engineers.
Natural Ventilation — Bob H. Reed, Research Architect, Texas Engineering Experiment Station.

Second Session: Product Engineering

Engineering Properties of Glass—Dr. Leighton Orr, Pittsburgh Plate Glass Co.
Windows in Modern Architecture — Bruno Funaro, Assistant Dean, School of Architecture, Columbia University.
Wood Windows — James Arkin, Architectural Consultant for the Architectural Woodwork Institute and the National Woodwork Manufacturers Association, Inc.
Steel Windows — William Gillet, Vice-President, Fenestra, Inc.
Aluminum Windows — John P. Jansson, Executive Vice-President, Aluminum Window Manufacturers Association.
Glass Block — H. F. Kingsbury, Engineer, Pittsburgh Corning Corp.
Fixed Glass Installations — C. K. Sigler, Manager Engineering, The Kawneer Co.

THURSDAY, NOVEMBER 15

Third Session: Controls

Problems Requiring Controls — Viewpoint of the Owner — speaker to be announced.
Exterior Controls — Henry N. Wright, Architect, New York City.
Interior Controls — Sterling S. Bushnell, Vice-President, Breneman-Hartshorn, Inc.
Engineering of Controls Systems — E. F. Snyder, Controls Applications, Minneapolis-Honeywell Regulator Co.

Fourth Session: Standardization

Standardization of Windows — William Demarest, National Association of Home Builders.

Fifth Session: Design Applications

Residential Design, Architects' Viewpoint — William Keck, Architect, Chicago.
Residential Design, Research Viewpoint — Professor James T. Lendrum, Director, Small Homes Council, University of Illinois.
Office Buildings—Gordon Bunshaft, Skidmore, Owings & Merrill.
Commercial Installations — D'Anson Isly, Ketchum & Sharp, New York City Architects.
Schools — Alonzo J. Harriman, Alonzo J. Harriman, Inc., Auburn, Maine.

Sponsors of the Conference include the Aluminum Window Manufacturers Association, the Andersen Corp., the Architectural Woodwork Institute, Breneman-Hartshorn, Inc., E. K. Geyser Co., Libbey-Owens-Ford Glass Co., Kimble Glass Co., National Woodwork Manufacturers Association, Inc., Pittsburgh Corning Corp., and the Pittsburgh Plate Glass Co.

Annual Fundamentals Course Underway in New York

The Fundamentals of Illumination course, offered annually by the New York Section of I.E.S., is again this year comprised of twelve weekly two-hour classes from September 25 through December 18. The time: Tuesday evenings, 6:30 to 8:30; the place: Consolidated Edison Building, New York City; the text: the *IES Lighting Handbook*. The program:

September 25 — Theory of Light and Vision.
October 2 — Physics of Illumination (units and distribution curves).
October 9 — Illumination Calculations (point by point method and measuring instruments).
October 16 — Light Sources I (construction, circuitry and fixtures).
October 23 — Light Sources II.
October 30 — Light Sources III.
November 13 — Design of Interior Lighting (installations).
November 20 — Office and School Lighting.
November 27 — Store and Residential Lighting.
December 4 — Industrial Lighting.
December 11 — Outdoor Lighting (including street lighting and floodlighting).
December 18 — Maintenance and Economics.

R. V. Smith, of the Holophane Co., is serving as course coordinator and instructor for the first three sessions. Merle E. Haskins, Westinghouse Electric Corp., is instructor for the Light Sources classes; E. L. Gluck, McPhilbin Mfg. Co., for Interior Lighting Design, Office, School, Store and Residential Lighting; and H. J. Peters, of Consolidated Edison, for the final three sessions.

Tuition for the entire series is $10 for I.E.S./A.I.A. members; $20 to others.

Applications for Retired Membership

By action of the membership, the new retired membership classifications have become effective in the new fiscal year, beginning October 1, 1956. Privileges in these new grades, earned by long membership in the Society, include reduced annual dues ($5) with continued receipt of all Society mailings including the monthly Journal, ILLUMINATING ENGINEERING. Such members will be designated as Member, Retired; Associate Member, Retired; etc. Those who are interested and qualified (at last thirty years of membership and 65 years of age) should address a letter to the General Secretary at Headquarters, stating that they have retired from regular occupation in business or profession.

I.E.S. Gold Medal Nominations — January 1 Deadline

January 1 is the closing date for receipt of nominations for the I.E.S. Gold Medal. Nominations for this, the highest award of the Society, are invited from all members, for consideration by the Medal Award Committee.

The I.E.S. Gold Medal is awarded to give recognition to meritorious achievement which has conspicuously furthered the profession, art or knowledge of illuminating engineering. Candidates need not be members of the Society, nor citizens of the United States or Canada. Nominations may be made at any time by any member of the Society by presenting to the General Secretary, care of Society Headquarters, the name of the individual whose accomplishments are deemed worthy of such recognition. These may be in the field of engineering, design, applied illumination, optics, ophthalmology, lighting research, education, or administration and management.

In order for a candidate to be considered for the award, a letter requesting such consideration must be received at Headquarters before January 1 of the year. Nominations and records on file from previous years, as reviewed and referred to the incoming Committee by previous Medal Award Committees, will be considered along with new nominations.

CHARTER NIGHT of the Chinook Chapter, I.E.S., in Calgary, Alta., was attended by a large and enthusiastic turnout of members and guests (above). Presentation of the Charter was by Pacific Northwest Regional V-P Blair Plowman, who came from Spokane, Wash., for the occasion. In photo below are: left to right, Bob Underhill, Board of Managers; Joe Thomas, Canadian Regional V-P who came from Montreal; Don Little, Chapter Secretary; Mr. Plowman; Don Frost, Chapter Chairman; and Gerry Woods and Martin Vickers of the Board of Managers. Bob Mason, also a Manager, not in photo.

Chinook Chapter, I.E.S. Holds Gala Charter Night

Distinguished guests from near and far, a meeting place overlooking the Canadian Rockies (from where the famous Chinooks blow from which the Chapter takes its name), gifts, and the enthusiasm of those attending all contributed to the gala quality of the Charter Night of the Chinook Chapter in Calgary, Alberta.

Among the distinguished guests were Calgary's Mayor Don MacKay, who attended with his wife; U. S. Consul Kenneth Oakley, who spoke on the spreading of better living standards through the technical exchange of ideas; I.E.S. Canadian Regional V-P Joe Thomas from Montreal, and, perhaps most important to the Chapter, Pacific Northwest Regional Vice-President Blair Plowman who presented the Chapter's charter.

Other non-local dignitaries were Ralph McKenzie from Lethridge (150 miles away), Mr. and Mrs. R. C. B. Jarvis and Mr. and Mrs. Fred Dorward from Edmonton. Mr. Jarvis is Chairman of the new Edmonton Chapter, and Mr. Dorward was the I.E.S. Representative in Alberta and a driving power in the formation of the two Chapters.

The meeting was held at the city's new Municipal Airport, overlooking the beforementioned Rocky Mountain scenery at its best. Gifts were presented to the new Chapter by fellow Sections in the Region. The whole meeting was televised, appearing over Calgary TV station CHCT, and a tape recording of an interview with Mr. Plowman and Mr. Thomas was presented on a feature radio program throughout the city.

In short, name it, the Chinook Chapter did it.

Report on National Technical Conference To Be in November I. E.

The complete report on the I.E.S. Fiftieth Anniversary National Technical Conference, held in Boston September 17-21, will appear in the November issue of ILLUMINATING ENGINEERING. Photographs and reports of the special Golden Anniversary events will be featured, in addition to the technical program.

ANNUAL SUMMER CONFERENCE of the New England Section, I.E.S. was again held at the Peabody Country Club, Peabody, Mass., on August 2. Smiles appearing in group photo above attest to the good time enjoyed by everyone. On this occasion also, the Section presented the awards for its contest for My Most Interesting Lighting Job. In photo at right, left to right, are: Eugene Frost, second place winner; Alonzo Taylor, first place winner; Howard Basset, who made the presentations; and third place winner Walter Staples.

Lighting Library Planned By Chicago Groups

The Chicago Section of I.E.S. has, this year, organized a Library Committee, under the chairmanship of C. A. Basedow, whose first project will be the establishment of a central library of material on lighting. Cooperating in this project is the Chicago Lighting Institute, which is assigning a room in its new headquarters, when completed, to house the library. Manpower for running the library will be supplied by the Institute and the I.E.S. Section will provide the material.

The committee also hopes to build up a library of slides to be available for speakers in the Section.

School Vision Conference Held By Pennsylvania Groups

The Pennsylvania Optometric Association and The Reading Clinic of Temple University co-sponsored a School Vision Conference at Temple University, Philadelphia, October 15-17. Theme of the conference was "Sight, Light and Reading." The meeting was directed to school supervisors, school administrators, teachers, reading personnel, educators, psychologists, school nurses, members of Parent Teachers Associations, members of Service Clubs and optometrists. Purpose was to acquaint the participants with modern techniques in the field of vision and lighting as applied to the field of education and reading, with emphasis on the public school.

Street Lighting Slides Offered by E.E.I.

Sets of 21 street lighting slides and an accompanying script have just been prepared by the Street Lighting Committee of the Edison Electric Institute.

Covering the measurements of light, distribution of light, recommended practices, typical street layouts covering various traffic classifications, glare in relation to mounting height, lighting of intersections, etc., the slides are now available to the electric industry for showing to civic groups, municipal groups and others interested in street lighting.

A complete set of 21 2 x 2-inch slides (12 colored and 9 black and white) and script is priced at $16.50. Both are available on a 10-day free trial basis. Additional copies of the script are free of charge. For information write the Commercial Department, Edison Electric Institute, 420 Lexington Ave., New York 17, N. Y.

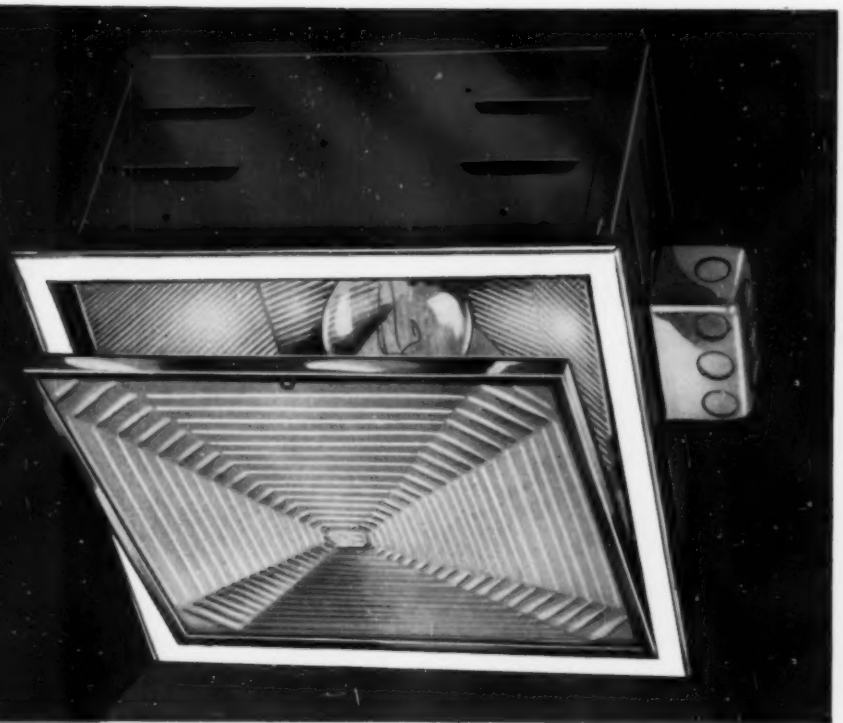
National Science Foundation Makes 289 Grants

The National Science Foundation has announced 289 grants totaling $3,504,227 awarded during the quarter ending June 30, 1956, for the support of basic research in the sciences, for conferences in support of science, for exchange of scientific information, for training of science teachers, and for the support for attendance of scientists at meetings abroad. This is the fourth and final group of awards to be made during the fiscal year 1956. Since the beginning of the program in 1951, 2495 such awards have been made, totaling almost $30,000,000.

The grants have been made to institutions and scientists from all over the continental United States, Hawaii, Puerto Rico, Great Britain and France. The research fields included are anthropology, astronomy, chemistry, biology, physics, earth sciences, engineering sciences, mathematical sciences, and socio-physical sciences. The research grants were approved by the National Science Board upon the recommendation of Dr. Alan T. Waterman, Director of the Foundation.

(Continued on page 12A)

Kirlin SYSTEM BUILT-IN Lighting



if you ask for it... INSIST on getting it!

YOUR LONG-RUN PROFITS DEPEND ON THE FIXTURE ITSELF!

If you are looking to a future increase in your business and your profits—be sure you get KIRLIN Fixtures when you ask for them. Their many advantages for your customers, and the greater light output, help to build good will for your business. Their many direct advantages to you, such as easier and quicker installation, make more money for you.

However, KIRLINs are being imitated in appearance just like the leading products in other fields are imitated. The distinctive color combination on recessed fixtures, the white frame and bright metallic door, was originated and *copyrighted* by KIRLIN; how many other makes can you name who have tried to make their fixtures "look like KIRLINs?"

These exclusive features and policies have yet to be equalled:

★ *GREATEST VARIETY OF LENSES*

★ *SOLD ONLY THROUGH TRADE CHANNELS*

★ *GENUINE GLASSURFACED ALUMINUM REFLECTORS*

• MADE IN ALL SIZES — SQUARE OR RECTANGULAR — AND IN FLUORESCENT

• WIDE-ANGLE OR CONCENTRATING LENS • EASILY INSTALLED BETWEEN JOISTS • IN STOCK AT LEADING WHOLESALERS • UL AND IBEW LABELS

LARGEST SELLING RECESSED LINE—MILLIONS IN USE EVERYWHERE

The KIRLIN CO. 3435 E. JEFFERSON AVE. DETROIT 7, MICHIGAN

FOOTCANDLES for maintaining house plants are demonstrated at the Minnesota State Fair by I.E.S. Twin City Section members Dick Graf, left, and A. B. Hallaway. Demonstration was sponsored by the Northern States Power Co.

Indoor Lighting for Plants Displayed at Minnesota Fair

A lighting demonstration on proper footcandles for maintaining certain popular house plants attracted thousands of visitors at the Minnesota State Fair this past summer. The display of plant lighting — in the 15-20 ft-c range, the 25-50 and 50-100 ft-c range — was the result of a four-way effort of the Residential Sales Department of Northern States Power Co., who provided the lighting; their Display Department which provided flower boxes by Frank Utecht; the University of Minnesota Department of Horticulture in the person of Roy Larson and the Minnesota Florists Association, who supplied the plants. Visitors picked up 5000 pieces of lighting information.

Manning the exhibit were Dick Graf, of the Builder Sales Department, and A. B. Hallaway, Supervisor of Residential Sales Department of the utility.

Lighting Education Award Announced for Second Year

For the second year, an award covering lighting activities of an educational nature conducted by operating electric light and power companies will be offered by the Better Light Better Sight Bureau, it was announced by H. A. Stroud, Promotion Manager, Monongahela Power Co., and Chairman of the Bureau.

The award, known as the Lighting Education Award, was given for the first time at the 1956 E.E.I. Sales Conference, covering activities of 1955. Purpose is to recognize noteworthy educational activities which foster a better public understanding of the relationship of light and sight.

Two bronze plaques are awarded, one to companies with 250,000 or more total meters, and one to companies with less than 250,000 total meters. Plaques covering 1955 activities were awarded to the Cleveland Electric Illuminating Co. and the Dayton Power and Light Co.

Chicago Lighting Institute Schedules Fall Quarter Courses

The lecture-laboratory courses on Fundamentals of Illumination, presented annually in the Fall quarter of the Chicago Lighting Institute's program, started this year on October 1, with Raymond E. Wozniak as instructor. The lecture classes are held weekly through December 17, and the laboratory sessions every two weeks.

Wiring Design Course 2A, Frank R. McShane, instructor, is also being offered, with classes every two weeks through December 4.

Classes are being held at the Institute's temporary offices in the Marquette Building, pending completion of the new headquarters in the same building.

IT SEEMS TO ME

Back-End-To Thinking?

"Under a uniformly luminous ceiling or an overcast sky the trouble-making peaks in these brightness curves would disappear." The foregoing sentence in our article on "Brightness Factors" in the August 1956 issue of ILLUMINATING ENGINEERING is of such importance in illumination design as to deserve more comment than was feasible within the space limits of that article. The brightness curve peaks referred to were those representing specular reflection in an observer's eye when looking at certain angles at glossy ink on glossy paper which rendered the letters impossible to read at those angles because of a reduction or reversal of the contrast ratio between paper and ink. The curves showed the ink to be brighter than the paper at the angles of specular reflection.

Papers and inks being what they are at the present day, every one who does any reading suffers from this nuisance. In office, drafting room and school room lighting, glare from paper is a frequent cause of fatigue and inefficiency; probably more common than glare from luminaires. Industrial tasks on shiny metal are also beset with this trouble. Nor is this trouble confined to artificial lighting.

We of the lighting profession have, over the past 50 years, been giving considerable attention in reports, recommendations, etc., telling users how to use our far-from-foolproof lighting methods so as to avoid these troubles from glare from paper and other glossy tasks. All of this was very well at the time, with the lamps and other materials we had to work with. But should not the advances of recent years raise a question in our minds whether we may have got into the habit of a kind of "back-end-to" thinking Should we not be thinking more about how to make our lighting systems suited to this task of reading in any convenient or desired positions on all kinds of paper and inks, rather than trying the hopeless job of getting people to use nothing but non-glossy papers and inks; especially in view of the fact that glossy papers and inks are a larger percentage of the total than ever; whether we like it or not. Our own official journal is an example.

There is no mystery about how to attain complete freedom from paper glare as we have plenty of lighting jobs that demonstrate it. But current lighting literature indicates that there is consider-

(Continued on page 17A)

Now the buyers of your fixtures are assured immediate "in-warranty" replacements of Sola ballasts, anywhere in the United States!

No delay! No red tape! No cost!

New Sola Ballast Service Plan enlists qualified electrical wholesalers all over the United States as ballast service centers.

- *Electrical Contractors get immediate replacement of any defective in-warranty Sola ballast — with a Sola or any equivalent certified CBM ballast of another make!*

- *Participating electrical wholesalers are provided sales aids to promote this new Sola replacement service to their contractors—plus their cost and contractor's resale profit on any Sola ballast replaced.*

SEE NEXT PAGE

Just what is the new

Sola Ballast Service Plan?

It's a revolutionary new plan which makes it possible for electrical contractors to get immediate replacement of any in-warranty defective Sola ballast, anywhere in the United States.

Any qualified electrical wholesaler who stocks certified CBM ballasts for over-the-counter sale can make the replacement. Wholesalers do NOT have to stock Sola ballasts to participate in the program, but can make replacements with *any* equivalent certified CBM ballast.

Participating electrical wholesalers will be designated as Sola Ballast Service Centers and will receive their original cost on replacements made, plus their full contractor's resale profit from Sola Electric Co. This applies to any Sola ballast replaced under the terms of the plan, regardless of the make of the certified CBM replacement.

Who benefits by the new Sola Ballast Service Plan?

The Fixture Manufacturer benefits because he's assured that the ultimate user, regardless of location, will get quick ballast replacement service in restoring his fixture to perfect operating order in those rare instances when a Sola ballast fails.

The User benefits because there's absolutely no delay in getting a new ballast to return his fixture to top working order, anywhere in the United States.

The Electrical Contractor benefits because he receives an immediate, free replacement for any in-warranty defective Sola ballast from his local wholesaler. The contractor keeps *his* customers happy with his service too.

The Electrical Wholesaler benefits because he recovers not only his cost but realizes his full contractor's resale profit on any in-warranty defective Sola ballast he replaces. He does not require any additional ballast stock. It's a real service to his customers, at a profit to him.

The Quality Standard of Sola Ballasts

The Sola Ballast Service Plan is made possible because Sola ballasts have an exceedingly low failure ratio. Less than 14/100-of-1% of *all* Sola ballasts fail in warranty, and less than 9/100-of-1% of Sola Rapid Start ballasts fail in warranty, according to carefully maintained records. This unusually low failure ratio is due to Sola's exceptionally high standards of quality in engineering and manufacturing.

CBM CERTIFIED by ETL

UL

Here's how the Sola Ballast Service Plan works

1. *Should an electrical contractor find a Sola ballast which has become defective within the warranty period, he returns it to any qualified electrical wholesaler anywhere in the United States. The wholesaler checks the date of manufacture stamped on the ballast cover. If the ballast failed within two years of its manufacturing date, it is considered "defective-in-warranty."*

2. *The electrical wholesaler is authorized by Sola Electric Co. to replace at no charge, the defective in-warranty Sola ballast with another Sola ballast if he has it in stock. If not, he refers to a Cross Index Ballast Replacement Guide, provided by Sola, to find an equivalent certified CBM ballast of any make.*

3. *The Wholesaler immediately gives the contractor the equivalent certified CBM replacement ballast from stock, and the contractor signs a receipt for it. The electrical wholesaler forwards a copy of the receipt with his invoice to Sola Electric Co. Sola credits him with his wholesale cost plus his full contractor's resale profit for the ballast replacement, just as if the replacement ballast transaction was a sale to the electrical contractor.*

4. *Within 30 days, Sola Electric Co. issues a check to the electrical wholesaler for the total value of any credit due him. Or, if the wholesaler prefers, Sola will credit the accrued amount against any Sola equipment he may wish to order.*

SEE NEXT PAGE

Write for information on the new Sola Ballast Service Plan

Sola ballasts are already recognized for superior design, construction, and performance. They are warehoused on both coasts and in the Midwest for prompt shipment. Qualified sales engineers are headquartered in every principal marketing area of the country to help you solve any service or technical problem that might arise. Now, in addition, Sola ballast service is expanded to include the most comprehensive replacement service plan in the industry.

This combination of quality, plus nationwide service, makes Sola ballasts your best choice for installation in your fixtures. Most likely you are already familiar with the superior quality and dependability of Sola ballasts. Now you can gain another tangible competitive advantage for your fixtures as a result of Sola's new Ballast Service Plan.

Mail the coupon below or phone for complete information on this unique ballast replacement plan. We will mail a detailed explanation to you promptly. If you wish, a sales engineer will call on you to give you any other information you may want to know about Sola ballasts or other products.

SOLA Electric Co.
4633 W. 16th St., Chicago 50, Ill.
Bishop 2-1414

TO: SOLA ELECTRIC CO.
4633 West 16th St., Chicago 50, Ill.

☐ Please mail a detailed explanation of the Sola Ballast Service Plan.

☐ Please have a Sola sales engineer call.

My name_____

My Title_____

Company_____

Address_____

City_____ Zone____ State_____

(*Continued from page 12A*)

able unclear thinking as to the essentials. These essentials are large, approximately uniform luminous areas. A theoretical ideal would be the daylight conditions on an open plain under a uniformly overcast sky, that is 6.28 steradians of luminous area. Fortunately very much less than this ideal gives very good practical relief from this trouble. But there is no definite line between complete relief from paper glare annoyance and enough to be annoying.

If we will leave our brightness meters at home and go out on inspection tours of artificial lighting jobs as well as some of nature's outdoor conditions, with a very simple and easily obtained testing "instrument" we are likely to find the expedition profitable. The writer has found it so. This instrument is simply a booklet or magazine printed on glossy paper (and how few are not) and the test method consists simply of reading this booklet in positions and places where shiny paper or things are to be worked with, and the more positions the better.

As a result of such explorations the writer has found the relief from paper glare troubles about as follows:

1. Complete relief for all practical purposes was found under:

(a) An apparently evenly overcast sky in an open field.

(b) An apparently evenly overcast sky in a yard surrounded by green foliage and light colored houses: the sky exposure roughly estimated as 2 steradians.

(c) A clear blue sky with the test paper in the shade on the north side of a building at mid-day, the same sky exposure and surroundings as (b).

(d) A clear blue sky with the test paper in the shade in a yard surrounded by two-story dingy brick buildings: the sky exposure not being over 2 steradians.

(e) Uniformly luminous ceilings, covering completely the working areas. The tests were made in large offices and drafting rooms, the ceiling panels being diffusing plastics. In some cases these working areas were divided by low partitions and acoustical baffles projected down from the ceiling.

2. Completely relief as in 1, except for slight troubles from curved paper held near walls was found under:

(a) Uniformly luminous ceilings in small rooms, such as a 5-desk office, where the luminous ceiling is surrounded with an opaque border. The trouble was near the walls. This suggests the avoidance of opaque borders as much as feasible, and that where duct space requires some opaque ceiling if feasible it be taken from more central areas and worked in to some ceiling design.

3. Incomplete relief, though considerable freedom from paper glare was found under:

(a) Louverall systems covering most of the ceiling; light coming straight down through the louvers causing the trouble.

(b) Ceilings ⅓ to ½ covered with fluorescent luminaires. In such cases the peaks of brightness reflected from the paper apparently overlap to smooth out these brightness peaks as viewed by the eye.

(c) Indirect lighting. This would be ideal but for the fact that it is not feasible to make the ceiling brightness uniform. However, for many years it was the best means we had in general lighting for getting relief from paper glare.

There seems to be a wrong idea abroad in the profession that indirect lighting and luminous ceilings give about the same lighting results, and properly belong in the same class. This is true only if the luminous ceiling is as non-uniform in brightness as the indirect lighted one usually is, which should not be the case. Any well-designed luminous ceiling, for use where relief from glare or other surfaces is important, must be approximately uniform in brightness as viewed by an eye looking up at it from the same position as a piece of glossy paper "looking"

(*Continued on page 42A*)

SCHEDULED EVENTS

1956

October 15-16, 1956 — United States Committee, International Commission on Illumination, Nittany Lion Inn, State College, Pa.

October 18-20, 1956 — Optical Society of America, Lake Placid, N. Y.

October 22-24, 1956 — American Standards Association, 38th Annual Meeting (In conjunction with Seventh National Conference on Standards), Hotel Roosevelt, New York, N. Y.

October 22-26, 1956 — National Safety Council, 44th National Safety Congress & Exposition, Chicago, Ill.

November 12-16, 1956 — National Electrical Manufacturers Association, Annual Meeting, Traymore Hotel, Atlantic City, N. J.

1957

January 21-25, 1957 — American Institute of Electrical Engineers, Winter General Meeting, Hotel Statler, New York, N. Y.

January 28-31, 1957 — Plant Maintenance & Engineering Conference, Public Auditorium, Cleveland, Ohio.

February 17-20, 1957 — National Electric Sign Association, Annual Convention and Exhibit, Sheraton Park Hotel, Washington, D. C.

February 25-28, 1957 — American Society of Heating and Air-Conditioning Engineers, 63rd Annual Meeting, Chicago, Ill.

February 25 - March 1, 1957 — 13th International Heating and Air-Conditioning Exposition, Chicago, Ill.

March 11-14, 1957 — National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

March 28-29, 1957 — Pacific Northwest Regional Conference, Illuminating Engineering Society, Empress Hotel, Victoria, B. C.

April 3-5, 1957 — South Pacific Coast Regional Conference, Illuminating Engineering Society, Hotel Statler, Los Angeles, Calif.

April 8-11, 1957 — Fourth National Electrical Industries Show, 71st Regiment Armory, New York, N. Y.

April 11-12, 1957 — Inter-Mountain Regional Conference, Illuminating Engineering Society, Hilton Hotel, Albuquerque, N. M.

April 28-30, 1957 — Southwestern Regional Conference, Illuminating Engineering Society, Holiday Inn, Oklahoma City, Okla.

April 28 - May 3, 1957 — Society of Motion Picture and Television Engineers, Shoreham Hotel, Washington, D. C.

May 6-8, 1957 — Air Conditioning and Refrigeration Institute, Annual Meeting, The Homestead, Hot Springs, Va.

May 9-10, 1957 — Midwestern Regional Conference, Illuminating Engineering Society, Hotel Astor, Milwaukee, Wis.

May 13-14, 1957 — Great Lakes Regional Conference, Illuminating Engineering Society, Pantlind Hotel, Grand Rapids, Mich.

May 16-17, 1957 — Canadian Regional Conference, Illuminating Engineering Society, Hotel Sheraton Brock, Niagara Falls, Ont.

May 23-24, 1957 — East Central Regional Conference, Illuminating Engineering Society, William Penn Hotel, Pittsburgh, Pa.

June 4-6, 1957 — Chicago Electrical Industry Show, Conrad Hilton Hotel, Chicago, Ill.

June 12-13, 1957 — Northeastern Regional Conference, Illuminating Engineering Society, Hotel Statler, New York, N. Y.

June 24-28, 1957 — American Institute of Electrical Engineers, Summer General Meeting, Montreal, Que.

August 28-30, 1957 — American Institute of Electrical Engineers, Pacific General Meeting, Yakima, Wash.

September 9-13, 1957 — Illuminating Engineering Society, National Technical Conference, Biltmore Hotel, Atlanta, Ga.

October 6-11, 1957 — Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y.

October 7-11, 1957 — American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 21-25, 1957 — National Safety Council, 45th National Safety Congress & Exposition, Chicago, Ill.

November 11-15, 1957 — National Electrical Manufacturers Association, Traymore Hotel, Atlantic City, N. J.

November 18-21, 1957 — 10th Exposition of the Air-Conditioning and Refrigeration Industry, Navy Pier, Chicago, Ill.

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(Continued on page 23A)

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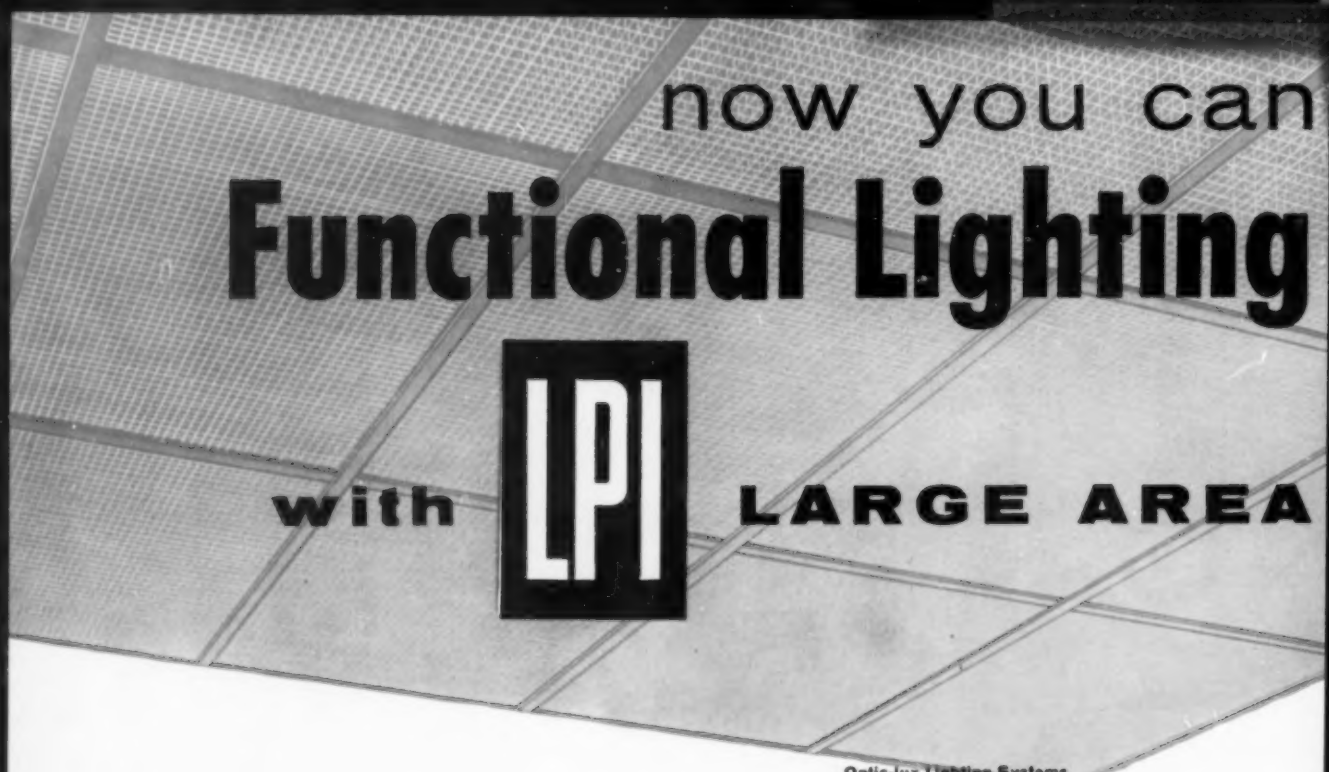

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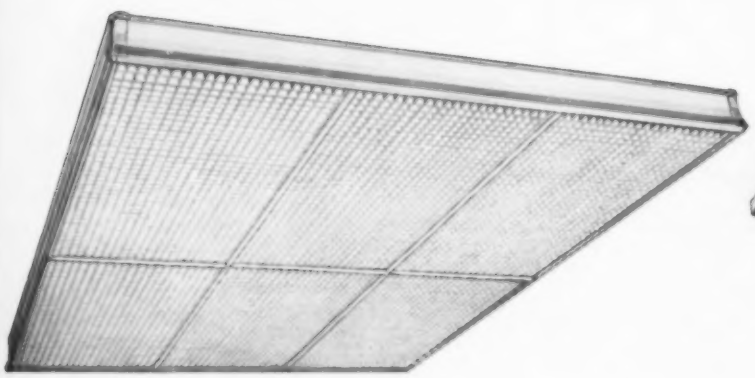

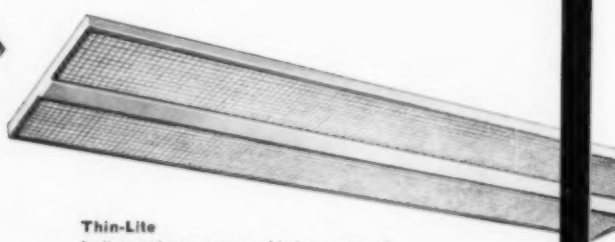

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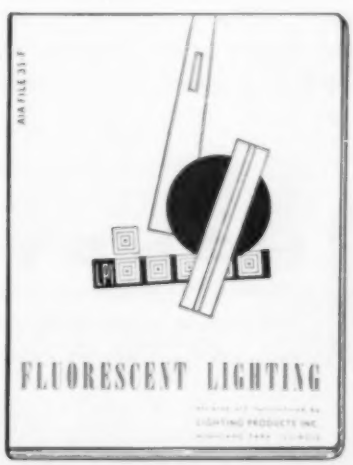

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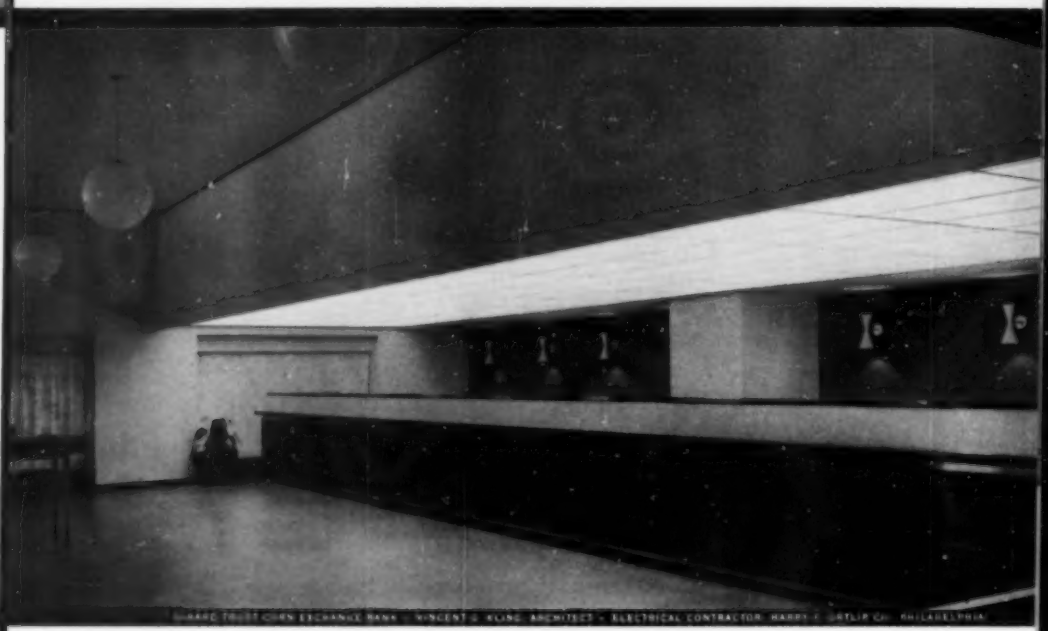

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(*Continued from page* 18A)

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(*Continued on page* 40A)

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All committees are appointed by the President, subject to approval of the Council and, except as provided in the Constitution, terminate at the time of the first Council meeting each administration, in the month of October. The scope of each committee is indicated.
M. N. Waterman, President, ex-officio member of all committees.

STANDING COMMITTEES

COUNCIL EXECUTIVE—To conduct the affairs of the Society between Council meetings.
M. N. Waterman, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

BOARD OF FELLOWS—To evaluate the eligibility of candidates for transfer to grade of Fellow according to procedures approved by the Council.
R. M. Evans, Chairman, Eastman Kodak Co., 65 Kodak Park, Rochester 4, N. Y.

FINANCE—To have direct supervision of the financial affairs of the Society and to present to the Council an annual report on its financial condition. To make recommendations to the Council as to the investment of moneys and upon all specific appropriations. To prepare and submit for approval of Council not later than the October meeting a budget of income and expense for the ensuing fiscal year.
W. P. Lowell, Jr., Chairman, Sylvania Electric Products, Inc., Salem, Mass.

GENERAL BOARD OF EXAMINERS—To investigate the qualifications of all applicants for admission to membership; to elect or reject applicants for the grade of Associate Member and Student Member, to report such action to the Council; and to make recommendation to the Council regarding applications for transfer or election to the grade of Member or Retired member, and for transfer to the grade of Member Emeritus.
Svend W. Bruun, Chairman, Rambusch Decorating Co., 40 W. 13th St., New York 11, N. Y.

MEDAL AWARD—To evaluate the eligibility of candidates for award of the I.E.S. Medal according to procedures approved by the Council.
Berlon C. Cooper, Chairman, McGraw-Hill Publishing Co., 330 W. 42nd St., New York 18, N. Y.

PAPERS—To procure, review and approve all technical papers and discussions thereof, for presentation before National Conferences of the Society.
H. F. Davidson, Chairman, Hydro-Electric Power Commission of Ontario, 620 University Ave., Toronto, Ont.

PUBLICATIONS—To be responsible for the procurement, review and approval of all material for the publications of the Society other than technical papers approved by the Papers Committee for presentation at National Conferences of the Society and their discussions and committee reports, for which it will have publication responsibility only. Shall also be responsible for the editing, printing and business management of the publications of the Society; specific exceptions may be made by Council.
J. S. Schuchert, Chairman, Duquesne Light Co., 435 Sixth Avenue., Pittsburgh 19, Pa.

GENERAL COMMITTEES

ADVANCE PLANNING—To study the operation, program, publication activities, membership classifications and financial structure with a view of its immediate and long-range objectives and to make recommendations to Council.
F. C. Winkler, Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland 1, Ohio.

ADVISORY BOARD TO THE PRESIDENT—To examine the organization, accomplishments, and assignments of committees and prepare not later than July 1 of each year a proposed list of committees and personnel; and to evaluate costs and benefits of present and proposed Society services.
Kirk M. Reid, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

ALLIED ARTS—To encourage and assist local competitions in allied arts, in cooperation with technical committees and interested local groups.
Karl A. Staley, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

BOARD OF NOMINATION—To prepare a nomination ticket containing the names of those who are deemed best suited to serve as officers and directors in positions to be filled at the ensuing election.
A. H. Manwaring, Chairman, Philadelphia Electric and Mfg. Co., 1228 N. 31st St., Philadelphia 21, Pa.

CONSTITUTION AND BY-LAWS—To prepare for Council proposed amendments to the Constitution.
G. F. Dean, Chairman, Toronto Hydro-Electric System, 14 Carlton St., Toronto, Ont.

DEFENSE COORDINATING—To contact various Government Agencies concerned with National Security suggesting cooperation and participation in specific projects as an aid to solution of their problems. Recommending the placement of lighting study projects in present committees or the appointment of study project committees to the Society President and to expedite such study projects and guide accepted reports into proper Government Channels.
J. W. Bateman, Co-Chairman, Canadian General Electric Co., Ltd., 212 King St., W., Toronto, Ont.

HISTORICAL—To assemble and make available for current reference and to prepare in suitable and durable form for posterity, such historical facts, printed memorabilia, photographs, voice records, museum specimens and allied items as may be judged worthy of composing a continuing digest of the record of the Society's history.
S. G. Hibben, Chairman, 31 Clinton Avenue, Montclair, N. J.

LIGHTING SERVICE—To stimulate and promote the discussion and practical application of lighting recommendations and to conduct a Lighting Service Forum in connection with the National Technical Conference.
L. E. Tayler, Chairman, The Detroit Edison Co., 2000 Second Ave., Detroit 26, Mich.

MEMBERSHIP—To develop plans and supervise the operation of the individual membership activity of the Society.
Brooks Chassaing, The Art Metal Co., Board of Education Bldg. 911 Locust St., Room 301, St. Louis 1, Mo.

NATIONAL TECHNICAL CONFERENCE—To be completely responsible, subject to the approval of Council, for the general coordination of all conference activities, for selecting and recommending time and place for review of the plans and budgets of the National Technical Conference Executive Committee and in cooperation with the Papers Committee for the satisfactory time allocation for the Technical Papers sessions, according to Procedures and Policies as adopted by Council.
J. C. Forbes, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

PROCEDURES AND POLICIES—To study problems of Society procedure and policy referred to the Committee by Council, and to formulate recommendations to Council for the statement, revision, or clarification of these procedures and policies consistent with the Constitution and By-Laws of the Society.
G. W. Beals, Chairman, The Miller Co., Meriden, Conn.

PUBLIC RELATIONS AND INFORMATION—To prepare and disseminate information about the activities, accomplishments, programs, objectives and policies of the Society and about the place of illuminating engineering in modern society; to formulate and submit public relations policies and plans for the Society.
J. R. Chambers, Chairman, Benjamin Electric Manufacturing Co., Des Plaines, Ill.

REGIONAL ACTIVITIES—To represent the respective Regions before the Council and to keep the Council informed regarding the affairs of the Regions. To stimulate Society activities, to encourage joint meetings of Sections and Chapters including Regional Conferences within the respective Regions, and to promote the expansion of the Society.
George J. Taylor, Chairman, Day-Brite Lighting, Inc., 161 East 42nd St., New York 17, N. Y.

RESIDENCE LIGHTING FORUMS—To stimulate and assist the Residence Lighting Forums of the Society and to encourage the formation of additional Forums. To conduct a Residence Lighting Forum in connection with the National Technical Conference.
Ruth Morris, Chairman, Georgia Power Co., P. O. Box 1719, Atlanta 1, Ga.

SUSTAINING MEMBERSHIP—To develop plans and supervise the operation of the Sustaining Membership activity in the Society according to the Procedures and Policies adopted by Council.
Fred E. Guth, Chairman, The Edwin F. Guth Co., 2615 Washington Ave., St. Louis 3, Mo.

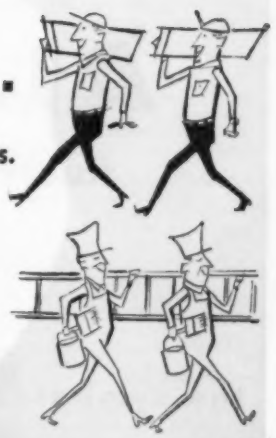
TRUSTEES, I.E.S. HEADQUARTERS RETIREMENT PENSION PLAN
D. M. Jones, Chairman, Curtis Lighting of Canada, Ltd., 991 St. Antoine St., Montreal, Que.

TASK COMMITTEE

I.E.S.-U. S. PUBLIC HEALTH SERVICE—To outline a method of making a survey of the visual factors of the working environment and the workers' vision and evaluating the findings in terms of visual comfort and effectiveness and eye health.
J. F. Parsons, Chairman, Niagara Mohawk Power Corp., Electric Bldg., Buffalo, N. Y.

(*Continued on page* 27A)

THE LIGHTS THAT GO IN WHEN THE PAINTERS GO OUT...



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Gibson ORTHO Fixtures need not be stored on the job where they're in the way of workmen and in danger of damage. Actually, Gibson ORTHO Fixtures can be delivered to the job the day before occupancy, because each fixture simply snaps into place in a matter of seconds, just as it comes from the box —sparkling clean, factory-fresh.

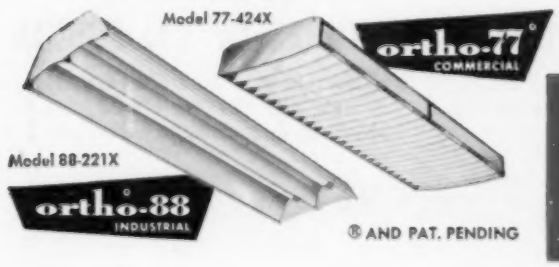
If you're interested in better lighting with savings of more than 50% on installation costs, then you really ought to know more about the Gibson ORTHO Line for industrial and commercial applications. Drop us a line. We'll send you the whole story.

1. WIRED ON THE FLOOR • A special channel (UNI-RACE) of telescoping 4' or 8' sections is assembled and wired on the floor, then lifted as a unit and mounted directly on joists, I-beams or stems. Saves hours of labor.

2. READY FOR THE FIXTURES • The UNI-RACE in place showing the built-in receptacles at 48" intervals. While the building is under construction, it will serve as a source of power for tools and temporary lighting.

3. SNAP—AND IT'S UP! • When the painters have left, the fixtures can be delivered to the building and snapped into place as fast as they are unboxed. Each fixture has a built-in plug which engages the receptacle in the UNI-RACE. Fixtures align themselves automatically.

4. VARIABLE SPACING • Fixtures may be installed in continuous rows or spaced at intervals of 4, 8, 12 or more feet. Units may be added, removed or rearranged any time without tools. Special "fill-in" sections close the UNI-RACE where no fixtures are mounted.



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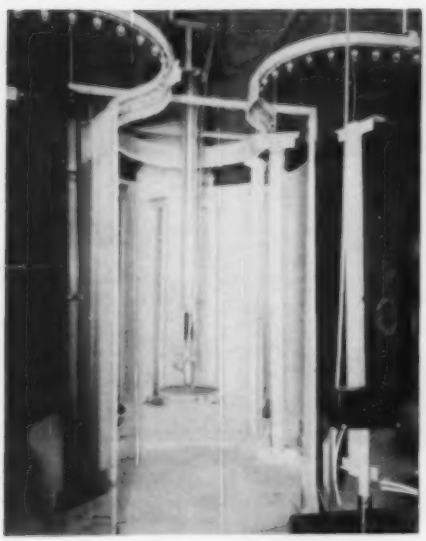

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(*Continued from page* 24A)

TECHNICAL COMMITTEES

AVIATION — To study the application of light and lighting to the spaces and functions involved in the operation of aircraft.

COLOR — To study, evaluate and report on the effect of color in relation to the art and science of illumination.

DAYLIGHTING — To study the problems involved in daylighting, develop recommended practices and report thereon.
H. B. Vincent, Chairman, Owens-Illinois Glass Co., 1700 N. Westwood Ave., Toledo, Ohio.
J. W. Griffith, Vice-Chairman, Southern Methodist Univ., Dept. of Engineering Res., Dallas, Texas.

DESIGN PRACTICE — To study published data on coefficients of utilization, room indexes, maintenance coefficients and other elements entering into calculations for lighting design; develop standard methods for use in Society publications and report thereon.
B. S. Benson, Jr., Chairman, Benjamin Electric Mfg. Co., Des Plaines, Ill.
W. M. Potter, Vice-Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

EDUCATION — To prepare educational and training programs on the fundamentals of illumination, lighting design problems and advance theories of light and lighting application. To prepare required text material and to further their adoption locally.
H. H. Magdsick, Chairman, 15925 Van Aken Blvd., Cleveland 20, Ohio.
R. S. Wiseman, Vice-Chairman, Engineer Research & Development Laboratories, Fort Belvoir, Va.

FARM — To study the application of light and lighting of farm buildings, surrounding work areas and other rural locations and to report thereon.

HANDBOOK REVISION — To revise and arrange the technical content of the Handbook; to lay out, plan and arrange for development of individual sections primarily through appropriate technical committees; to consult with the Publications Committee on its presentation of a suitable publication budget for Council approval; to be responsible to Council for the accuracy and treatment of material including the format and paging.
J. J. Neidhart, Chairman, Miller Co., Meriden, Conn.

IES-ASHAE — (American Society Heating & Airconditioning Engineers). Joint Committee — To study the relationship between lighting and various factors that enter into the thermal environment and report thereon.
R. W. McKinley, Chairman, Pittsburgh Plate Glass Co., 1 Gateway Center, Pittsburgh 22, Pa.

INDUSTRIAL — To initiate, follow up and coordinate lighting study projects in the industrial field, review the reports of the various subcommittees in this field and make recommendations to Council.
W. H. Kahler, Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland 1, Ohio.

Central Station Properties
L. G. Parks, Jr., Chairman, Ebasco Services, Inc., 2 Rector St., New York, N. Y.

Clothing
Norman Kridel, Chairman, Rochester Gas & Electric Co., 89 East Ave., Rochester, N. Y.

Foundries
E. A. Linsday, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

Graphic Arts
Ralph Enghouser, Chairman, Sylvania Electric Products, Inc., 4700 Parkside Ave., Philadelphia, Pa.

Outdoor Productive Areas
Elden H. Witte, Chairman, Benjamin Electric & Mfg. Co., Des Plaines, Ill.

Revision of Recommended Practice
E. A. Linsday, Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

Sawmills
James Barnes, Chairman, Pacific Gas & Electric Co., P. O. Box 540, San Rafael, Calif.

INSTITUTIONAL — To initiate, follow up and coordinate lighting study projects in the field of public buildings and private institutions, review the reports of the various study subcommittees in this field and make recommendations to Council.
Leonard V. James, Chairman, 513 S. Catherine Ave., LaGrange, Ill.

Auditoriums and Churches
George Shoemaker, Chairman, Pennsylvania Power & Light Co., 1000 Chestnut St., Philadelphia, Pa.

Hotels
C. I. Sayles, School of Hotel Administration, Cornell University, Ithaca, N. Y.

Theaters
Joel E. Rubin, Chairman, Kliegl Bros., 321 W. 50th St., New York 19, N. Y.

LIGHT CONTROL & EQUIPMENT DESIGN — Collect and correlate the knowledge and data on means and methods of controlling, directing, reflecting, transmitting and diffusing light and on the principles and practices of equipment design.
Eric H. Church, Chairman, Lighting Products, Inc., 1549 Park Ave., W. Highland Park, Ill.
John T. McLaughlin, Vice-Chairman, Kelso-Burnett Electric Co., 225 W. Jackson Blvd., Chicago 6, Ill.

LIGHT SOURCES — To correlate and report available information as to the physics of light and light production and the characteristics of current light sources.
E. H. Salter, Chairman, Electrical Testing Labs., Inc., 2 East End Ave. & 79th St., New York 21, N. Y.
George Freeman, Vice-Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

MAINTENANCE — To study the elements contributing to maintenance factors; set up the framework of typical field studies to determine factors; and to stimulate the prosecution of such studies by appropriate agencies.
Francis Clark, Chairman, Lighting Services, 515 Meridan Road, Waterbury, Conn.

MOTOR VEHICLE (EXTERIOR) — To study the problems of illuminating the night operations of motor vehicles and to make suitable recommendations for promoting maximum safety and convenience including accessory illuminated signal and traffic aids.
R. P. Teele, Chairman, National Bureau of Standards, Washington 25, D. C.

NOMENCLATURE — To define the terms and standards of illumination, and endeavor to obtain uniformity in nomenclature.
Priscilla Presbrey, Chairman, Westinghouse Electric Corp., Bloomfield, N. J.

OFFICE — To study the lighting requirements of office lighting tasks, develop suitable lighting recommendations and report thereon.
G. F. Dean, Chairman, Toronto Hydro-Electric System, 14 Carlton St., Toronto, Ont.

PROGRESS — To keep in touch with developments in the art of lighting throughout the world and prepare a yearly review of achievements in the art of illuminating engineering for inclusion in ILLUMINATING ENGINEERING.
J. H. McCulloch, Chairman, Independent Testing Labs., 1928 Fourteenth St., Boulder, Colo.
J. C. Forbes, Vice-Chairman, General Electric Co., Nela Park, Cleveland, Ohio.

PUBLIC CONVEYANCES — INTERIOR LIGHTING — To study the application of light to all public areas in conveyances used for passenger transportation, including particularly trains, buses, ships, street railways and subways, and report thereon.
E. Boghosian, Chairman, Dept. of the Navy, Bureau of Ships, Code #350, Washington 25, D. C.

RESIDENCE — To study and report on the application of light and lighting in residences; to develop performance recommendations for residence luminaires and to prepare necessary educational aids.
F. J. Marriett, Chairman, Thomas Industries, Inc., 410 S. Third St., Louisville 2, Ky.
E. W. Halteman, Vice-Chairman, Pennsylvania Power & Light Co., 534 Main St., Bethlehem, Pa.

SCHOOL — To study the application of light and lighting to the spaces and processes involved in educational institutions and to report thereon.
J. M. Chorlton, Chairman, Board of Education, 155 College St., Toronto 2B, Ont.
Carl Allen, Secretary, General Electric Co., Nela Park, Cleveland 12, Ohio.

SEARCHLIGHT — To study the design and application of searchlights and to report thereon.
J. A. Bartelt, Chairman, Dept. of the Navy, Bureau of Aeronautics, Code EL-S 211, Washington 25, D. C.
W. A. Pennow, Vice-Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland 1, Ohio.
Thomas W. Cushing, Secretary, Hanovia Chemical & Mfg. Co., Room 422, Washington Bldg., Washington, D. C.

Executive
J. A. Bartelt, Chairman, Dept. of the Navy, Bureau of Aeronautics, Code EL-S 211, Washington 25, D. C.

Bibliography
J. P. Latil, Chairman, Genarco Inc., 97-04 Sutphin Blvd., Jamaica, N. Y.

Light Sources
R. E. Faucett, Chairman, Engineering Research and Development Laboratories, Fort Belvoir, Va.

Nomenclature
Ernest Boghosian, Chairman, Dept. of the Navy, Bureau of Ships, Code 560, Washington 25, D. C.

Optics
D. Petersen, Chairman, Bausch & Lomb Optical Co., Rochester, N. Y.

Revision of IES Handbook
T. H. Projector, Chairman, National Bureau of Standards, Washington 25, D. C.

Testing Procedures
T. H. Projector, Chairman, National Bureau of Standards, Washington 25, D. C.

Visibility of Sources
W. A. Pennow, Chairman, Westinghouse Electric Corp., 1216 58th St., Cleveland 1, Ohio.

Visibility of Targets
L. R. Noffsinger, Chairman, National Bureau of Standards, Washington 25, D. C.

SIGNAL LIGHTING, ELEMENTS OF — To compile a compendium of current information on all phases of signal lighting.
F. C. Breckenridge, Chairman, National Bureau of Standards, Washington 25, D. C.

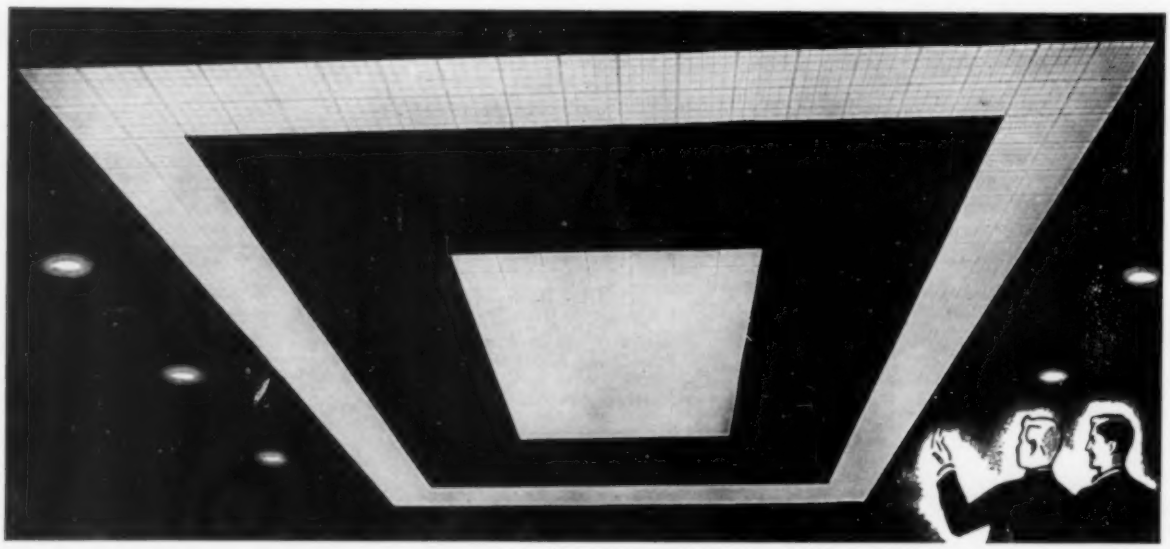
SPORTS AND RECREATIONAL AREAS — To develop current recommended practices for lighting sports and recreational areas; study techniques of application including effects on player performance and spectator visibility and report thereon.
F. D. Wyatt, Chairman, 427 Cottage Hill Ave., Elmhurst, Ill.
M. W. Ross, Secretary, Commonwealth Edison Co., 72 W. Adams St., Chicago 90, Ill.

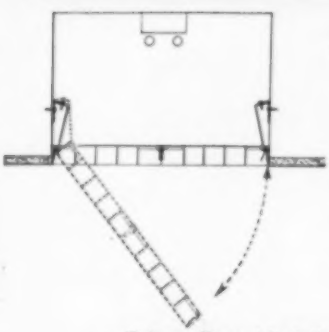
(*Continued on page* 38A)

There is a place for

Dramatic LUVE-TILE

in every new building...or re-lighting job





- "**Luve-Tile**" can be hinged down from either side or completely removed for cleaning.
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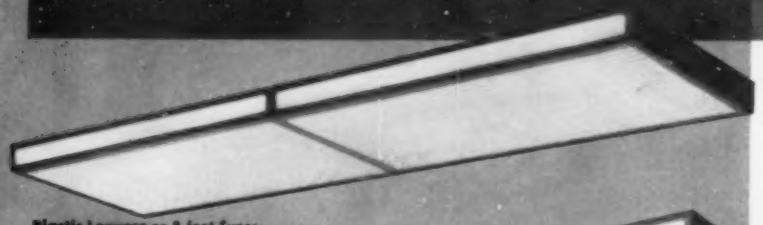
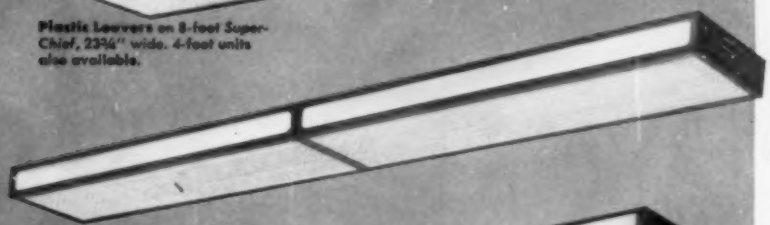
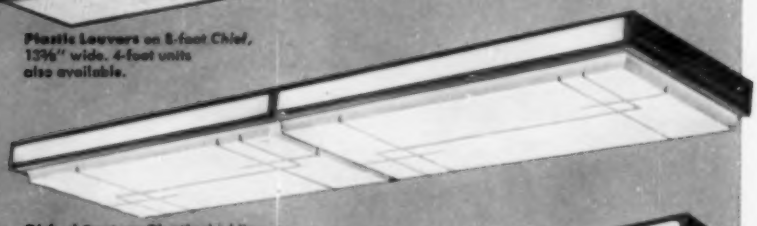


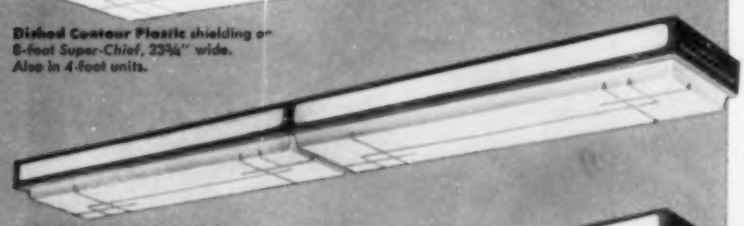
Plastic Louvers on 8-foot *Super-Chief*, 23¾" wide. 4-foot units also available.



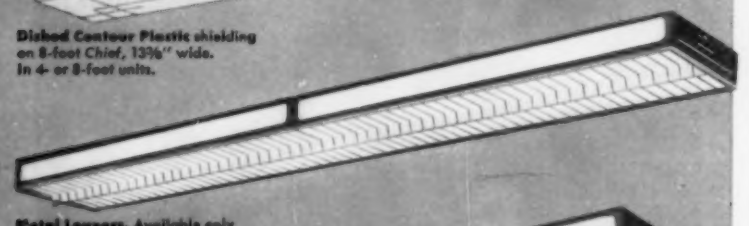
Plastic Louvers on 8-foot *Chief*, 13⅜" wide. 4-foot units also available.



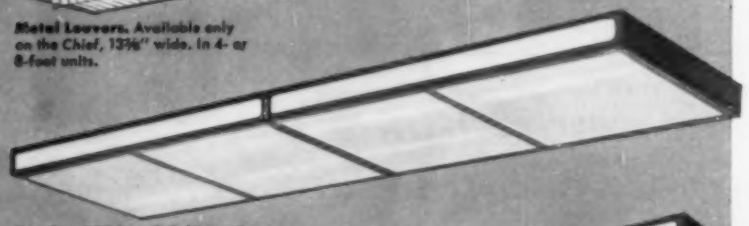
Dished Contour Plastic shielding on 8-foot *Super-Chief*, 23¾" wide. Also in 4-foot units.



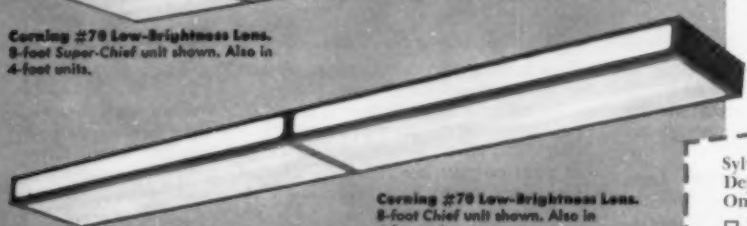
Dished Contour Plastic shielding on 8-foot *Chief*, 13⅜" wide. In 4- or 8-foot units.



Metal Louvers. Available only on the *Chief*, 13⅜" wide. In 4- or 8-foot units.



Corning #70 Low-Brightness Lens. 8-foot *Super-Chief* unit shown. Also in 4-foot units.



Corning #70 Low-Brightness Lens. 8-foot *Chief* unit shown. Also in 4-foot units.

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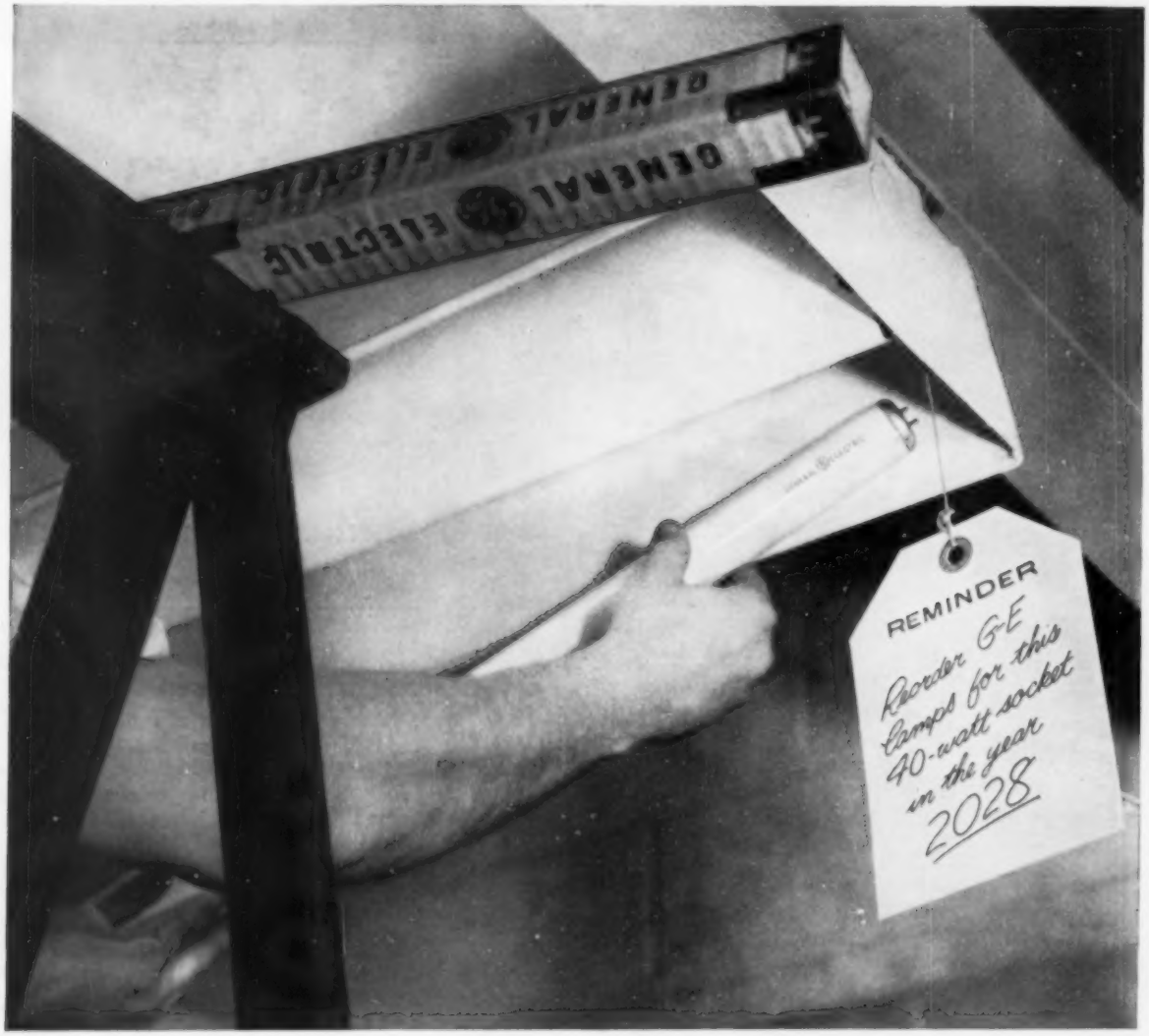


General Electric fluorescent lamps "should live so long"...*and they do!*

IT would be most unusual for you to buy a whole carton of 24 G-E 40-watt fluorescent lamps to keep a single socket supplied. If you should, however, based on the average service life of 3 years per lamp, you wouldn't need to buy another lamp for that socket for 72 years . . . until the year 2028!

HOW G-E LAMP UNIFORMITY AFFECTS LIFE—Long life is important, but also important is *uniformity of life*—the "spread" between the first and last burnouts in a group of lamps. After one year of service in single shift plants an average of 99 out of 100 General Electric 40-watt fluorescents will still be burning. That's 2500 hours of service. In double shift plants, 98 of 100 will be burning after a full year! General Electric 40-watt fluorescent lamps not only live up to their published rating of 7500 hours life, but have virtually no early failures.

GENERAL ELECTRIC LAMPS SAVE YOU MONEY. Lack of early failures can help cut your lighting costs. For example, G-E lamp uniformity lets you set up and stick to a group relamping schedule, cutting maintenance costs. Fewer individual lamps to spot replace.

In addition to uniform *life*, General Electric 40-watt fluorescent lamps on the average are 99.9% free from physical defects that could affect performance in service! And they are uniform in light output; less than 1% of all G-E 40-watt fluorescent lamps are as much as 5% below their published light output of 2500 lumens.

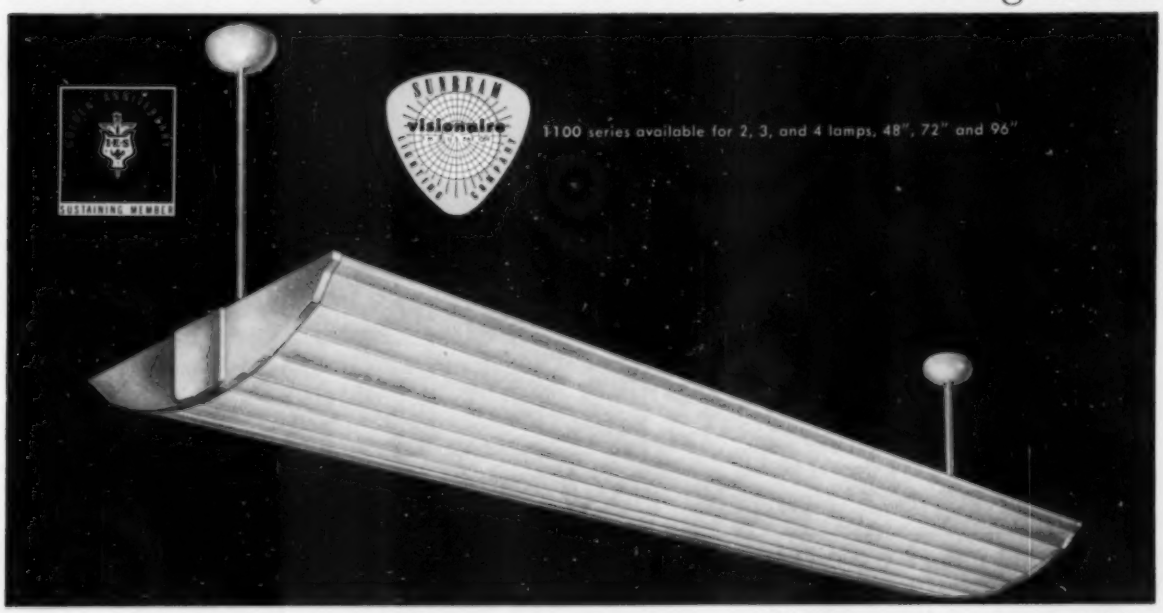
For more information on how you benefit from G-E fluorescent lamps write: General Electric Co., Large Lamp Dept., IE-10, Nela Park, Cleveland 12, Ohio.

Progress Is Our Most Important Product

GENERAL ELECTRIC

READ HOW EASY it is to perform difficult visual tasks with the new, totally indirect Sunbeam Lighting **1100** series. The unusually broad distribution of uniform, glareless, low brightness, high intensity illumination produced by this pendant Visionaire establishes new concepts of visual comfort. With its soft, eye-easy, luminous effect and clean-lined beauty, this **all-white** unit is perfectly designed for schoolrooms, offices, drafting rooms and other areas where the seeing task is critical.

Consider also the long-range savings available with this **all-metal,** low maintenance Visionaire. Parallel metal louvers allow circulating air currents to keep louver and lamp surfaces dust free. After mounting easy-to-handle fixture frame by **"hook-on"** method, the shielding cradle



hinges into place without tools for quick installation. The **1100** series relamps from the top without removing any part of fixture. Units available for use with higher lumen lamps, typical of today's trend. All metal parts are Bonderite-treated for lifetime corrosion resistance. Write for Bulletin 747 today.

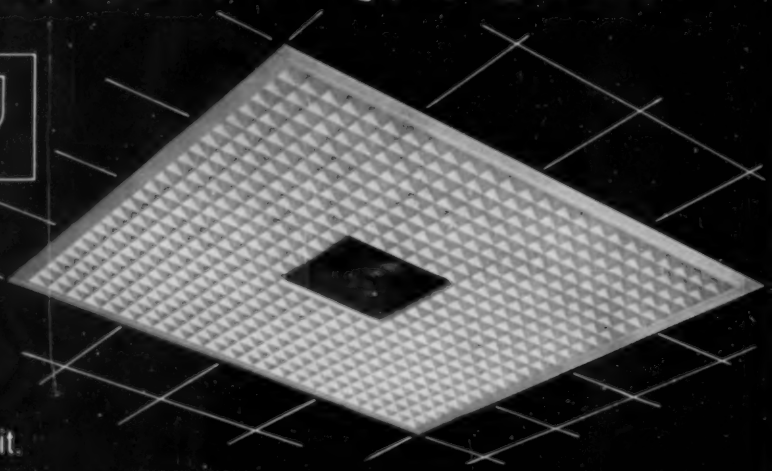
Sunbeam Lighting Co., 777 E. 14th Pl., Los Angeles 21, Calif.

Best Salesman In The Store!

GARCY

No. RS7900

Provides the
efficiency of fluorescent
... the color rendition of
incandescent, in a single unit.



An outstanding unit, combining incandescent light to high-light merchandise with sparkle and warmth—and a high-level of well-diffused fluorescent light for comfortable overall seeing. Hinged, one-piece aluminum louver offers maximum rigidity, minimum weight. Can't come apart, can't sag. Utilizes six or eight 48" Rapid-Start fluorescent lamps and one 200 or 300 watt incandescent lamp directly above a glass lens in the center of the egg-crate type louver.

SPECIAL—Unique Alzak* aluminum reflector controls and blends fluorescent and incandescent light. No spash of incandescent . . . no contrast of fluorescent and incandescent colors on surface of fixture.

*T.M. Aluminum Company of America

Above: Garcy No. RS7900 units installed in John Wanamaker's, Wynnewood, Pennsylvania

GARCY 5600 LUMINAIRES FOR LUXURY LIGHTING

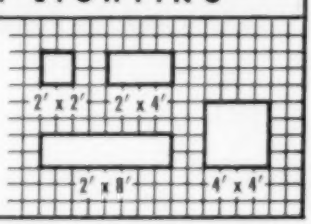
Available with THREE TYPES OF SHIELDING

Plastic panel in hinged frame
Hinged one-piece louver
Glass panel in hinged frame

VARIETY IN SIZE AND NUMBER OF LAMPS

2′ x 2′—Two, three or four lamp rows
2′ x 4′—Two, three or four lamp rows
2′ x 8′—Two, three or four lamp rows
4′ x 4′—Six, eight or ten lamp rows

Choice of rapid start fluorescent or slimline lamps



Send for Bulletin—552 L

GARCY Quality by *Design*

Garden City Plating & Mfg. Co., 1760 N. Ashland Ave., Chicago 22, Illinois
In Canada: Garcy Co. of Canada, Ltd., 1244 Dufferin Street, Toronto 4

Specify the perfect lighting for every activity and mood

. . . through LUXTROL Light Control

Make a special hit with your clients!

Show them something **really new!** Bring them face to face with lighting convenience they never imagined was possible. LUXTROL Light Control!

Your clients will be sold on LUXTROL just as soon as they see it demonstrated. As soon as you, or they, turn a LUXTROL dial to **any level of light. From dark to full bright!**

With LUXTROL Light Control at their finger tips, your clients can picture themselves entertaining more graciously. Enjoying soft, romantic light for dining. Full light for cards. Subdued light for TV . . . or home movies.

LUXTROL does away with noisy, old-fashioned on-off switches. Controls both incandescent and fluorescent lighting. **It is not a rheostat . . . but a cool, efficient, safe autotransformer.** Made with precision. Approved by Underwriters' Laboratories. And the price is agreeably low.

Consult your electrical contractor for interesting facts about this new concept of lighting. We'll send you his name . . . and literature. Mail the coupon.

THE SUPERIOR ELECTRIC COMPANY
4106 Demers Ave., Dept. I
Bristol, Connecticut

Please send me full design data on new LUXTROL *Light Control . . . and the names of electrical contractors in my area.*

Name_____

Street_____

City_____ Zone____ State_____

This School Lighting is Easy on the Pupils

Yes, this school lighting installation is easy on the pupils — and easy on the pocketbook, also. It features a *standard* Litecontrol fixture, our No. 6628, pendant mounted. The fixture is very simple to install because of its two-piece construction. Its curved sides eliminate dust pockets and can be cleaned in a jiffy.

This modern, well-lighted classroom with light finishes and almost no shadows shows how harmful contrasts can be eliminated. Note that intensity is somewhat higher than conventional classroom installations. Tests have proved that children in a classroom will cut down intensities as much as 25% as compared with an empty room. Thus, the youngsters here benefit by an extra quantity of high quality illumination.

Whether your next lighting job is a school, bank, library, shop or office . . . LITECONTROL fixtures will give you the right kind of light, in the right amount, in the right places — at the right price. See your local Litecontrol Representative.

INSTALLATION: Londonderry School, Middletown, Penna.

ARCHITECT: William Lynch Murray & Associates Harrisburg, Pennsylvania

ELECTRICAL CONTRACTOR: C. R. Kilgore & Son, Camp Hill, Pennsylvania

DISTRIBUTOR: Dauphin Electrical Supplies Company

MOUNTING HEIGHT OF FIXTURES: Approximately 9'-0"

SPACING: 7'-0" on center

FIXTURES: No. 6628 2 lamp pendant fixtures, hung on 12" stems

INTENSITY: Average throughout room, 55 footcandles in service

LITECONTROL

Fixtures

KEEP UPKEEP DOWN

LITECONTROL CORPORATION

36 PLEASANT STREET, WATERTOWN 72, MASSACHUSETTS

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

Fixtures: Holdenline Co., Cleveland, O.

The use of Corning Pattern No. 70 Lens Panels creates comfortable glarefree light on work surfaces in this modern office.

Use this lens panel for glareproof commercial lighting

You use Corning Pattern No. 70 to deliver maximum light in the useful zone with low brightness in the glare zone.

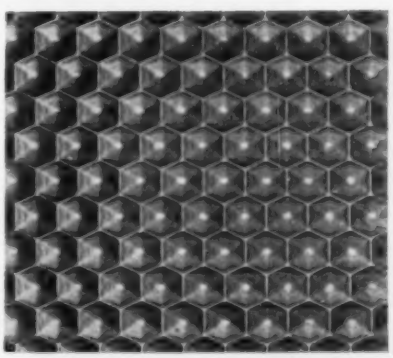
Use it to get better lighting installations in stores, banks, offices—wherever you want low brightness, glare-free light.

A pattern of hexagonal prisms on one surface controls the light. These prisms bend light rays downward creating more useful illumination. Light in the near horizontal angles is reduced so that surface brightness of the panel is low at normal viewing angles.

Result is a distribution of emitted light in a pattern of even illumination on the working surface.

Lightweight—and you can get panels up to 100 inches long—for one-piece fixtures that eliminate dust- and light-leaking seams. Water-white crystal, dimensionally stable glass. Won't warp, fade, discolor, or show age. Has no dust-attracting static charge. Cleans easily.

For free information about this interesting and useful lightingware, please use the coupon.



Close-up view of Pattern No. 70, a prismatic crystal lens panel. You can get Pattern No. 70 in widths up to 34 inches, lengths up to 100 inches.

SUSTAINING MEMBER

CORNING GLASS WORKS
CORNING, N.Y.

Corning means research in Glass

CORNING GLASS WORKS, 61-10 Crystal Street, Corning, New York

Please send me Bulletin LS-47A: "New Corning Pattern No. 70 Low-Brightness Lens Panel."

Name.....Title.....

Firm.....

Address.....

City.....Zone.....State.....

THE ENGINEER WAS CORNERED!

There was a lighting engineer in Des Moines (don't ask us his name) on whom we'd never made much of a dent. Then, suddenly, he specified Miller Lexingtons for a really big job.

"I was visiting a client," he told us, "and noticed his office was lighted with Lexingtons. Very attractive. Later, I went by the new school to pick up my son. Never saw such a well lit classroom! Lexingtons again. Finally, on the way home, I stopped to pick up a new cord for my wife's iron. The shop had just been relighted and really looked wonderful. Lexingtons!

"By this time, I figured I was cornered. Any luminaire that's good enough and versatile enough to do such separate lighting jobs just couldn't be overlooked. So—I called in your representative, got the facts, and specified Lexingtons for my next big job."

How about *your* next big job? To find out all about Miller Lexingtons, drop us a line—or call your Miller representative.

miller

Better Lighting for a Brighter America

THE MILLER COMPANY: GENERAL OFFICES, MERIDEN, CONN.
FACTORIES: UTICA, OHIO—MERIDEN, CONNECTICUT.
IN CANADA: CURTIS LIGHTING OF CANADA LTD. TORONTO.

THE MILLER *"Lexington"*

GENERAL CHARACTERISTICS: A direct-indirect fluorescent luminaire, combining a pleasing appearance with maximum seeing comfort. 60% of the light is thrown upward into the ceiling to produce shadowless, indirect light throughout the room. Downward light is thoroughly shielded to prevent direct glare.

AVAILABLE • in two-lamp or four-lamp widths • with steel or plastic side panels • with louvers providing 35°-45° or 45°-45° shielding • for pendent or surface mounting • with top reflector plates for ceiling mounting

IN THESE SIZES:

4-foot length, for two 48" rapid-start or slimline lamps
8-foot length, for four 48" rapid-start or two 96" slimline lamps
4-foot length, for four 48" raid-start or slimline lamps
8-foot length, for four 96" slimline lamps

This G-E development engineer is testing a ballast design for a new fluorescent application. He's a member of the largest ballast development group in the industry. The fundamental research which they perform is one important reason why G.E. is the leading supplier of fluorescent ballasts.

Flora* shows you how . . .

General Electric Ballast Design Leadership Helps You Save Lighting Dollars

General Electric's design leadership has contributed greatly to the vast fund of knowledge now available and being used by the entire ballast industry.

A recognized pioneer in ballast design, G.E. has led in these important developments: Tulamp lead-lag, certified series 96T12, trigger start, rapid start, clamped core, plastic sign, and dimming ballasts. G.E. emphasizes product leadership to provide the best ballast value to the user. We have never resorted to the temptation of lowering product quality to gain competitive advantage. Instead, we furnish only the best ballasts to assure economical fluorescent lighting. We're convinced there is no substitute for satisfactory performance.

To be sure of top quality ballasts with the latest design developments, look to the leader . . . General Electric!

The next time you specify equipment for a fluorescent lighting installation, make sure you get the best . . . specify General Electric ballasts.

A G-E ballast tag or sticker on your fixture is proof that it's equipped with the best in ballast value. It's the only way to be certain. For further information on G-E ballasts, write Section 401-15, General Electric Co., Schenectady 5, New York.

*Miss Fluorescent Ballast, G. E.'s Ballast Mascot

Copyright 1955, General Electric Company

USER SATISFACTION gets foremost consideration by G-E ballast development engineers. Here a ballast is being checked to make sure it will provide optimum light output and lamp life.

Five more reasons why

GENERAL ELECTRIC IS YOUR BEST BALLAST VALUE

- EXCLUSIVE SOUND RATING SYSTEM
- SUPERIOR QUALITY CONTROL
- LONGER BALLAST LIFE
- PRECISE LAMP-MATCHED DESIGN
- COMPLETE CUSTOMER SERVICES

Progress Is Our Most Important Product

GENERAL ELECTRIC

It's *EXTRUDED* Acrylic Sheet

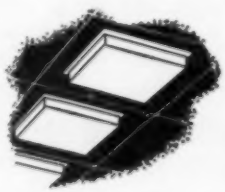
It's GERLITE

Quality Controlled

Brings you new advantages — extra strong, forms more easily, costs less!

Just imagine Acrylic sheets that are stronger and lower in cost than you've ever seen — sheets that can be deep drawn to shapes never before considered practical . . . and you begin to get an idea of what you can do with Gerlite. Extrusion technique makes Acrylic sheets seem almost a new material for all lighting and sign applications!

Years of Gering experimental work are behind *extruded* Gerlite. Years of testing in lighting and sign applications prove Gerlite meets every requirement! Sheets are available clear or colored, to 54" wide, to .125" thick, any practical length. Gerlite can be painted or silk-screened easily with existing paints now in use. Stands up to weather, gives long dependable service. Why not write now for full information and prices!



GERLITE

EXTRUDED ACRYLIC SHEET

GERING PRODUCTS, INC.
KENILWORTH, N. J.

Mail Coupon Today!

GERING PRODUCTS INC.
Kenilworth, N. J.

Please send me full information on Gerlite.

Name _____ Title _____

Company _____

Address _____

City _____ Zone _____ State _____

I.E.S. Committees

(Continued from page 27A)

STANDARDS OF QUALITY AND QUANTITY FOR INTERIOR ILLUMINATION — To prepare standards for illumination levels, brightness limits, brightness ratios for interiors, including specific visual tasks, as well as the general surroundings.
Glenn A. Fry, Chairman, School of Optometry, Ohio State University, Columbus 10, Ohio.

STORE — To study the application of light and lighting to the spaces and processes involved in the selling of goods and to report thereon.
C. M. Cutler, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.
Lester Geis, Vice-Chairman, Garden City Plating & Mfg. Co., 23 W. 47th St., New York, N. Y.

Service Station and Parking Areas
E. H. Schaefer, Chairman, Wisconsin Electric Power Co., 231 W. Michigan St., Milwaukee 3, Wisc.

STREET AND HIGHWAY — To establish the scientific principles underlying street and highway lighting; to collect data on the results of the application of such principles to actual practice; to prepare such reports thereon as will assist technicians and benefit the public.
G. K. Glass, Chairman, Detroit Edison Co., 2000 Second Ave., Detroit 26, Mich.
D. W. Rowten, Vice-Chairman, Westinghouse Electric Corp., 1216 W. 58th St., Cleveland 1, Ohio.
T. Seburn, Secretary, Bureau of Highway Traffic, Strathcona Hall, Yale University, New Haven, Conn.

TECHNICAL COMMITTEE FORUM — To coordinate procedures of our technical committees and to sponsor a lighting application symposium at the National Technical Conference.
Kirk M. Reid, Chairman, General Electric Co., Nela Park, Cleveland 12, Ohio.

TELEVISION — LIGHTING FOR PRODUCTION — To study and report on the lighting for production of television programs.
Walter O'Meara, Chairman, National Broadcasting Co., 30 Rockefeller Plaza, New York 20, N. Y.

TESTING PROCEDURES FOR ILLUMINATION CHARACTERISTICS — To prepare standard test procedures for illumination characteristics of light sources, lighting equipment and illumination materials, and to report thereon.
A. E. Krawcek, Chairman, Crouse-Hinds Co., Syracuse 1, N. Y.

Residence Lighting Resource List Available from Headquarters

A 29-page multilithed bibliography, compiled by the I.E.S. Committee on Residence Lighting, is available, free of charge, in limited quantity from the I.E.S. Headquarters, Technical Department. The list was compiled especially for educators, home lighting advisors and students as a guide to current authoritative sources of associated study, research, development and recommended practice. Titles and a short description of each publication are classified according to the following categories: nature of light, light and vision, light sources, luminaires, lighting design principles, recommended lighting methods, housekeeping functions, architecture, interior design and furnishings, color, wiring, and visual and teaching aids.

new dimension...

in fixture value with THE *new* SMITHCRAFT FINISH

Smithcraft now adds a new dimension in fixture perfection. The new Smithcraft painting process consists of the finest and most modern Bonderite and Baked Enamel Finish combination in use in the lighting industry today.

In addition to its superior appearance, the new Smithcraft finish has these outstanding qualities:

Adheres firmly to metal — Stays white indefinitely, without yellowing — Provides positive resistance to chemicals and heat — Resists abrasion because of optimum hardness — Reflects a maximum percentage of light

Because the new Smithcraft finish possesses all these attributes to a greater degree than ordinary finishes, it produces many important new benefits for owners and users of lighting — better appearance, better lighting qualities, easier maintenance and longer, trouble-free life.

All the units in the complete and diversified line of Smithcraft commercial and industrial fixtures are now finished with this new process. Typical is the Sheraton (shown above) — a trim, modern unit, only 3¼" deep; the Sheraton is ideal for low-ceiling applications. It is available for two and four-lamps in 4-ft. and 8-ft. lengths. Plan to use the Sheraton in your next school, store or office design.

Ask us to send you the current Smithcraft catalog — it is a compilation of the newest and most functional fluorescent fixtures in use today

Smithcraft
LIGHTING
CHELSEA 50 MASSACHUSETTS

America's finest fluorescent lighting

Ask these questions, too, when you judge a fluorescent lamp...

Is your investment protected?

Check Westinghouse Fluorescent Lamps against any other brands you are now using. Check them for maintained brightness, long life, uniform appearance. If you are not entirely satisfied on all counts, your full purchase price will be refunded.

Is it the correct type, size and color for the lighting job to be done?

In the Westinghouse fluorescent family of 290 different lamps—including Slimline and Rapid Start—there's a type and size precisely right for every office, plant and store application. Colors include seven different shades of "white" alone.

How about quality control?

From raw materials to finished product, every Westinghouse fluorescent lamp is subjected to *480 inspections and tests* before approval for shipment.

For the full story on how to get more for your money in fluorescent light, contact your Westinghouse Lamp Representative.

WATCH WESTINGHOUSE

WHERE BIG THINGS ARE HAPPENING FOR YOU!

I.E.S. Section/Chapter Officers

(Continued from page 23A)

San Jose Chapter — South Pacific Coast Region

Chairman — GEORGE BAKER, Pacific Gas & Electric Co., 86 S. 3rd St., San Jose 14, Calif.
Secretary — DON WARFIELD, General Electric Co., 999 98th Ave., Oakland 3, Calif.

Southeast Florida Chapter — Southeastern Region

Chairman—J. V. SHELLHORSE, Florida Power & Light Co., 25 S. E. 2nd Ave., Miami 30, Fla.
Secretary — FRED WILLIAM MARKLAND, Graybar Electric Co., 2111 N. W. 22nd Ave., Miami, Fla.

Southern California Section — South Pacific Coast Region

Chairman — GEORGE A. HOCHENAUER, Benjamin Electric Mfg. Co., 923 E. Third St., Los Angeles 13, Calif.
Secretary — ROY E. BEVAN, Sylvania Electric Products Inc., 2936 E. 46th St., Los Angeles 58, Calif.

Southern Colorado Chapter — Inter-Mountain Region

Chairman — ROBERT F. EVEN, Southern Colorado Power Co., 115 W. 2nd St., Pueblo, Colo.
Secretary — LES JOHNSON, Pueblo Electric Supply Co., 131 Spring St., Pueblo, Colo.

Southwestern Section — Southwestern Region

Chairman — JOHN B. DECK, JR., Texas Power & Light Co., P. O. Box 6331, Dallas 2, Texas.
Secretary — E. L. COLE, Dallas Power & Light Co., 1506 Commerce, Dallas 1, Texas.

Suwanee River Chapter — Southeastern Region

Chairman — A. H. BRUNING, Georgia Power & Light Co., Valdosta, Ga.
Secretary — ARTHUR T. CRABTREE, Union Electric Supply Co., 207 W. Hill Ave., Valdosta, Ga.

Tar Heel Section — Southeastern Region

Chairman — A. L. DUCKER, JR., General Electric Co., Greensboro, N. C.
Secretary — JAMES A. LOWE, Duke Power Co., Drawer K-1, Greensboro, N. C.

Tennessee Valley Section — South Central Region

Chairman — JOE W. FOWLER, Joe Willis Factory Sales Agency, 601 Fifth Ave., Nashville, Tenn.
Secretary — HARRY W. BOURGEOIS, 1805 Harjes St., Nashville 4, Tenn.

Toronto Section — Canadian Region

Chairman — GRANT E. DAVIDSON, Hydro Electric Power Commission, 620 University Ave., Toronto, Ont.
Secretary — E. MACHTINGER, Crouse-Hinds Co. of Canada Ltd., 7-21 Labatt Ave., Toronto, Ont.

Twin City Section — Midwestern Region

Chairman — A. A. ARONSON, Northern States Power Co., 15 S. Fifth St., Minneapolis, Minn.
Secretary — F. T. TILLEMANS, Westinghouse Electric Corp., 2303 Kennedy St., N. E., Minneapolis 13, Minn.

Twin Ports Chapter — Midwestern Region

Chairman — KENNETH PETERSON, Westinghouse Electric Corp., 100 Elizabeth St., Duluth, Minn.
Secretary — ERIC G. NYLUND, Nylund Electric Co., 5723 Grand Ave., Duluth 7, Minn.

Utah Section — Inter-Mountain Region

Chairman — WAYNE F. MULCOCK, Utah Power & Light Co., 138 S. Main St., Salt Lake City 10, Utah.
Secretary — EARL DON PETERSON, Utah Power & Light Co., 138 S. Main St., Salt Lake City 10, Utah.

Vancouver Island Chapter — Pacific Northwest Region

Chairman — A. S. HARRIS, B. C. Electric Co., 1501 Douglas St., Victoria, B. C.
Secretary — WALTER E. BEEK, B. C. Electric Co., 1501 Douglas St., Victoria, B. C.

Virginia Chapter — East Central Region

Chairman — D. N. JENKS, General Electric Co., 1004 N. Thompson St., Richmond 21, Va.
Secretary — T. P. HARRIS, 6037 Bonneau Road, Richmond 27, Va.

Western Michigan Section — Great Lakes Region

Chairman — W. DALE CRITES, 1377 Biscayne Way, Haslett, Mich.
Secretary — WILLIAM WINGLAR, J & G Dorenman Co., 301 Keeler Building, Grand Rapids 2, Mich.

Western New York Section — Great Lakes Region

Chairman — BYRON F. LYTH, JR., Niagara Mohawk Power Corp., 535 Washington St., Buffalo 3, N. Y.
Secretary — LEO P. GAUTHIER, Sylvania Electric Products Inc., 407 Jackson Bldg., Buffalo 2, N. Y.

Winnipeg Chapter — Canadian Region

Chairman — D. J. BOURDON, Amalgamated Electric Corp. Ltd., 677 Notre Dame Ave., Winnipeg, Man.
Secretary — M. SPIGELMAN, City of Winnipeg, Hydro Electric System, 55 Princess St., Winnipeg, Man.

Yankee Chapter — Northeastern Region

Chairman — ARTHUR C. BRODEUR, JR., Western Massachusetts Electric Co., 65 State St., Springfield, Mass.
Secretary — BARTHOLOMEW D. BARRY, JR., Northern Berkshire Electric Co., 21 Bank, St., North Adams, Mass.

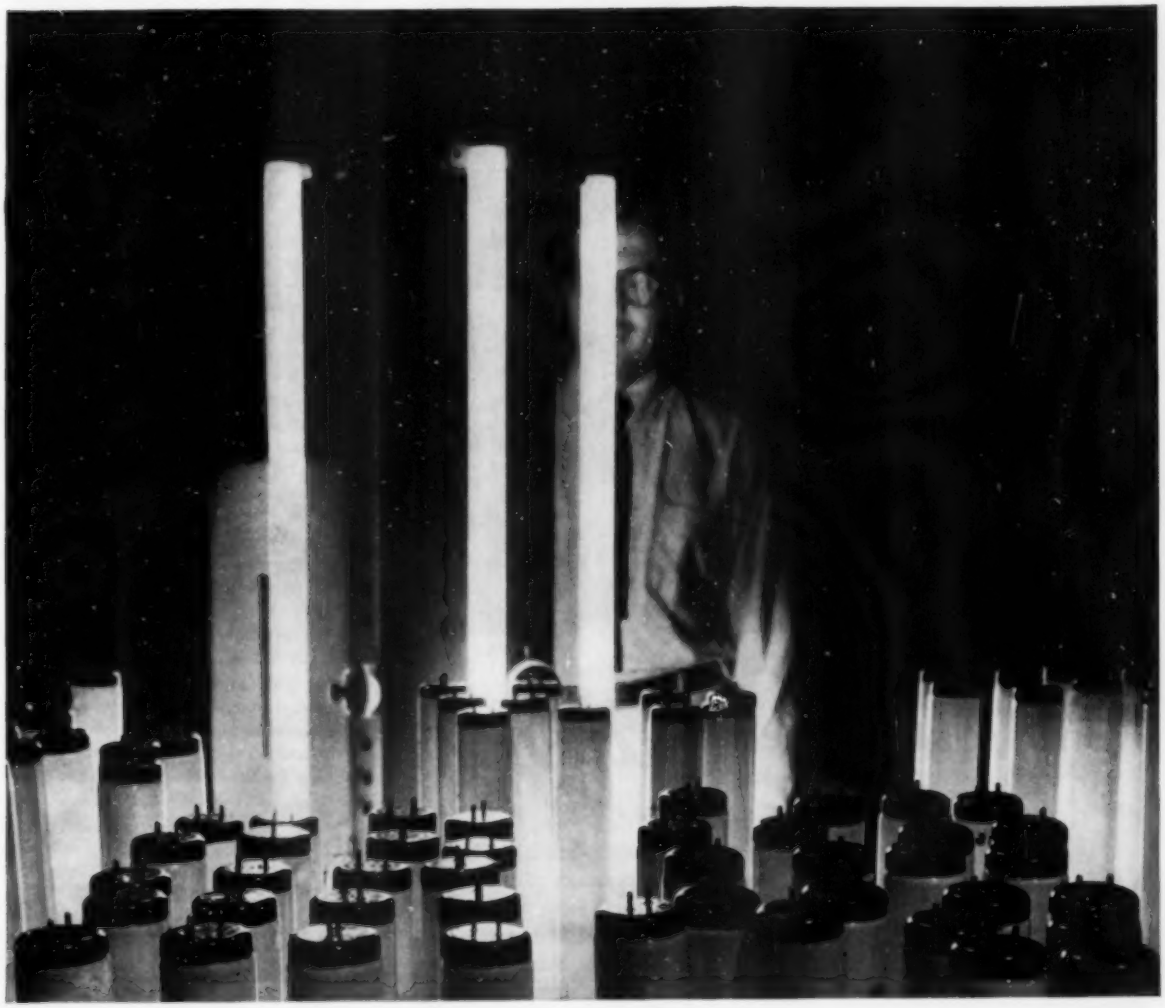
I.E.S. National Technical Conferences

1957 — September 9-13 — Biltmore Hotel, Atlanta, Georgia

1958 — August 17-22 — Royal York Hotel, Toronto, Ontario

1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California

how to judge a fluorescent lamp . . . point no. 8



ask about COLOR MATCH

You can be sure that the Westinghouse fluorescent lamp you buy today will exactly match the Westinghouse lamp of the same color classification you bought yesterday or years ago. Two facts guarantee it. *First*, to insure strictest uniformity, Westinghouse makes all of its own lamp phosphors, the tube-coating materials that determine lamp color. *Second*, Westinghouse (and only Westinghouse) uses "drift-free," *Halo-type* Phosphors throughout its entire fluorescent lamp line.

WATCH WESTINGHOUSE

*WHERE **BIG** THINGS ARE HAPPENING FOR **YOU!***

Kopp Lenses

make air travel Safer

SUSTAINING MEMBER

Perhaps no business or industry is more aware of the importance of safety than air transportation. Both planes and airports are equipped with every practical device to insure safe take-offs and landings, and smooth danger-free flights en route.

For years Kopp Lenses have been contributing a significant role in safe airport operation. Here Kopp Lenses display their extreme dependability on every count—accurate beam control, color transmission, weather resistance and others.

If the continuous, safe operation of your products depends on lenses, sight glasses, color filters or other glass parts, you can depend on Kopp to provide the characteristics you need.

KOPP GLASS

KOPP GLASS, Inc.

Swissvale, Pennsylvania

(Continued from page 17A)

up at it would be read. Such design not only gives the best conditions for work on glossy things but automatically takes care of direct glare. The two evils, direct and reflected glare, go hand in hand, with the none too well recognized exception that in the case of work on paper, as in offices, drafting rooms, and schools, direct glare may be well guarded against by using a louverall system which does not guard against reflected glare from paper, as in case 3(a) before-mentioned.

We are fortunate that advances in cheap light production, cheap light weight, high light transmission and sound absorbing, diffusing plastics and light weight supporting structures have combined to make the uniformly luminous ceiling economically feasible for places where there is sufficient density of room occupancy and where it is most needed because the users have the least chance to shift their work to non-glare positions, as for example in large offices, drafting rooms and school rooms.

It is also fortunate that, in addition to the luminous ceiling's advantages as an aid to easy seeing conditions, it has in many cases architectural and acoustical advantages that may be equally conducive to its selection.

Yet to be solved are problems of making the luminous ceiling and wall economically available for places where they are not quite so much needed, but nevertheless desirable, such as living rooms and other rooms occupied by few people, but where much reading or work on glossy things is done. JAMES R. CRAVATH, *2152 Ward St., Berkeley 5, Calif.*

ABOUT PEOPLE

Robert Thallon has been appointed to the newly created position of director of engineering and operations for Fluorescent Fixtures of California, with his office in the company's general offices and manufacturing center in South San Francisco. Mr. Thallon formerly served in the dual capacity of chief engineer and assistant sales manager.

Brooks Chassaing, Sales Manager for The Art Metal Co., has announced the appointment of the following sales representatives. **Paul Roth,** of Detroit, Mich., covering the Detroit and Toledo, Ohio trading areas; **M. Morin Rivera** of New Orleans for the states of Louisiana and Mississippi and the Mobile, Ala., area; **D. L. Donelson** of Omaha and **Harold**

Thompson of Rock Island, Ill., covering the states of Nebraska, Iowa and northwestern Illinois; **Charles W. Carr,** of Pittsburgh, in western Pennsylvania, northern West Virginia and the eastern counties of Ohio; **Harold Mulhauser,** Douglas, Mich., to cover the western Michigan territory.

The Philadelphia Electric Co., in reorganizing its Sales Department, has promoted, among others, the following I.E.S. members: **M. I. Allen,** Vice President in Charge of Sales; **P. M. Alden,** Sales Manager, Residential and Commercial Sales Dept.; **C. C. Shotwell,** Assistant Sales Manager, Industrial Sales Dept.; **J. F. Roberts,** Manager, Residential and Commercial Sales Division; **D. S. Bean,** Assistant Manager, Residential and Commercial Sales Division; **R. M. Hoot,** General Supervisor, Municipal Sales Section; **L. Albertson,** Supervisor, Sales Promotion Section.

The appointment of **Joseph G. Carroll** as manager of the Ken-Rad lamp department of Westinghouse Electric Corp., has been announced. Mr. Carroll, formerly works manager of the company's lamp works in Little Rock, Ark., will make his headquarters at Owensboro, Ken. It was also announced that **Charles T. Nichols,** manager of the company's Southern lamp plants will become works manager of the Little Rock plant in addition to his present responsibilities.

Prescolite Manufacturing Corp., Berkeley, Calif., has appointed **Juan Manrique** as its sales representative for the Republic of Cuba. Mr. Manrique has been associated with the sale of electrical products and lighting fixtures in Cuba since 1943, and in 1954 established his own manufacturers' representative firm, with headquarters in Havana.

Bertrand J. Farrell has been named Sales Manager of the Wholesale Division of Jefferson Electric Co., Bellwood, Ill. Mr. Farrell was formerly sales manager of the Redmond Co.

The appointment of **Frank Bernd** as Chicago sales manager, with responsibility for sales operations in Chicago, the northern counties of Indiana, northern Illinois and eastern Iowa, has been announced by Curtis Lighting, Inc. For the last six years, Mr. Bernd has been sales engineer in the company's Chicago and northern Indiana territories.

Raymond M. Waggoner, vice-president, Pacific Coast sales, for Hubbard and Co., has been appointed vice-presi-

(*Continued on page* 44A)

Another L&P Fixture on its Way . . .

Packed with **Quality**

Long before an L & P fluorescent light fixture is laid carefully into its carton—ready for prompt shipment to you—it is "packed" with quality. For quality is built right into every L & P fixture, every step of the way . . . from the precision-tooled dies made under our own roof to the last turn of a screw on our modern assembly line.

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ENDOVAL

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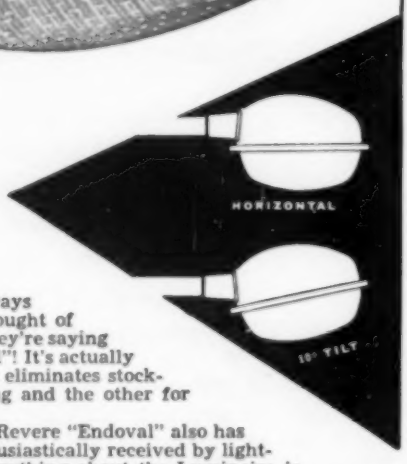

Of the good things... it's always said: "Why hasn't someone thought of that before?" And that's what they're saying about the New Revere "Endoval"! It's actually two luminaires in one—since it eliminates stocking one for horizontal mounting and the other for 10° tilt.

But, that isn't all... the New Revere "Endoval" also has a host of other advantages enthusiastically received by lighting engineers everywhere. Everything about the Luminaire is precision built! The housing is of precision, die-cast aluminum alloy. The reflector is of one-piece W-Modified Parabolic design which offers sharp, vertical cut-off and proper I.E.S. distribution patterns without the use of lifting prisms. You obtain fullest utilization of lamp output. Reflector cannot be inserted wrong. Perfect alignment assured at all times... cannot work loose .. no tools needed to release it!

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All the above, coupled with lightness in weight, greater strength, more attractive size and shape, finer finish, ample wiring area and simple terminal connections make the New Revere "Endoval" tops in design — tops in performance and tops in value. Investigate today. Write for Brochure 700-9.

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(*Continued from page 43A*)

dent and general manager of Pacific Coast operations. His enlarged duties will include management of the company's plant at Oakland, Calif.

The appointment of **Gordon W. Butler** to the position of St. Louis district sales manager for Westinghouse Lamp Division has been announced. Mr. Butler will make his headquarters at the company's sales offices at 411 North 7th St., St. Louis. Mr. Butler was formerly assistant to the Southwestern region manager of the company's lamp division.

Kuhlman Electric Co., Bay City, Mich., has named **Joel H. Watkins** as Vice-President in Charge of Sales, and **Arthur V. Hughes** as Vice-President and Director of Engineering. Mr. Watkins, who had joined Kuhlman Electric in 1953 as Sales Manager, will continue to head the sales activities of the company's three regional plants at Bay City, Mich., Crystal Springs, Miss., and Salinas, Calif. Mr. Hughes, who came to the company in 1951 as Director of Engineering, will continue to coordinate product development and engineering in the three transformer divisions.

Fluorescent Fixtures of California announces the following sales staff changes and promotions. **Richard E. Liepold,** will head northern California, Nevada, Utah and Idaho sales as San Francisco regional sales manager; **Mervin J. Hooey,** Seattle district sales engineer, was named regional sales manager for all districts except San Francisco. Office Sales Manager **Fred J. Bertolone** has been appointed assistant regional sales manager. **Thomas S. Rutherford,** formerly with Garcy Western Corp. is the new Office Sales Manager.

Globe Lighting Products, Inc., Los Angeles, has appointed the Gaines Co., with headquarters in Kansas City, Mo., as its sales and service representative in the Kansas-western Missouri area.

The Miller Co., Meriden, Conn., has appointed **Charles C. Wetmore** as sales representative for the Worcester-Providence territory with headquarters in Worcester, Mass. Mr. Wetmore has been associated with the Smith Electric Supply Co., Fall River, Mass., in an electrical supply sales capacity.

Deaths

Harry C. Zinsmeister, President and Director of Pittsburgh Reflector Co.

James D'Arcy, Jr., D'Arcy Electric Co., Georgia Section, I.E.S.

J. C. de la Rosa, Toronto Transportation Commission, Toronto Section, I.E.S.

design by mc Philben

EDGE-LITS—Smart new styling features . . . cast aluminum construction, satin finish . . . hinged access doors . . . Ask for the "45 line".

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Get the jump on competition by ordering Sheffield EVER-WHITE shields now. (If you have no die with us, one of our representatives will be glad to show you our complete line of stock dies, one of which may meet your requirements.)

For full details on EVER-WHITE shields, contact your nearest Sheffield representative or write to Sheffield Plastics, Inc., Dept. 61-5B, Sheffield, Mass.

PHYSICAL PROPERTIES OF POLYSTYRENE

PROPERTY	REGULAR GRADE	EVER-WHITE GRADE
Specific Gravity	1.05	1.05
Tensile Strength, lbs./sq. in.	7000	7000
Modulus of Elasticity	$4\text{-}5 \times 10^5$	$4\text{-}5 \times 10^5$
Impact Strength, Izod, ft. lbs./in. of notch	0.25-0.35	0.25-0.35
Thermal Expansion, In./in./°C	$6\text{-}8 \times 10^{-5}$	$6\text{-}8 \times 10^{-5}$
Heat Distortion, °F @ 264 p.s.i.	183-191	183-191
Light Transmission, in white translucent color, percent	1-70	1-70
Color Possibilities	Unlimited	Unlimited
Burning Rate, Inches/min.	1	1
Light Stability index, from actual exposure to light from fluorescent tube	1.0-1.5	>3.0*

* Sample still under test

Precision Engineered Rigid Plastics Extrusions

SHEFFIELD PLASTICS INC.
SHEFFIELD, MASS.

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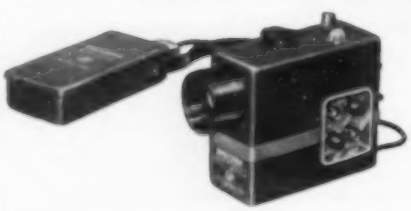

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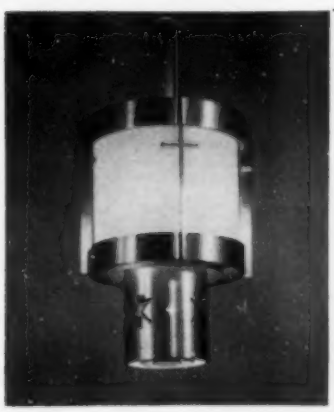

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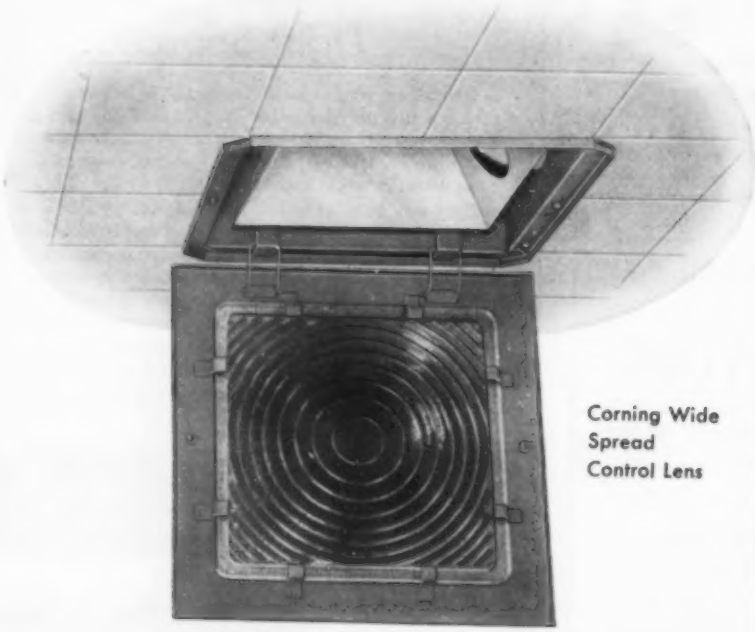

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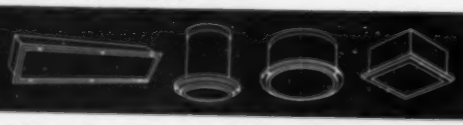

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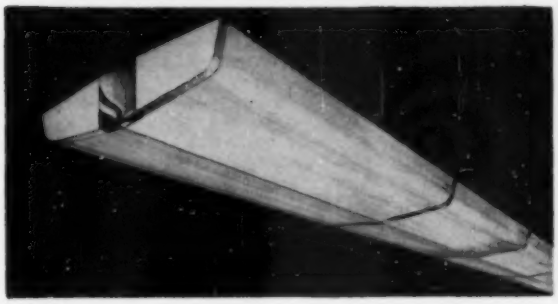

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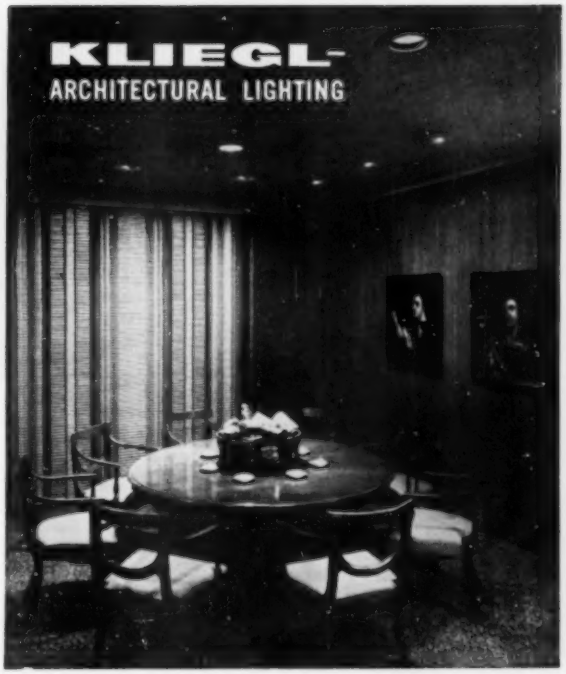

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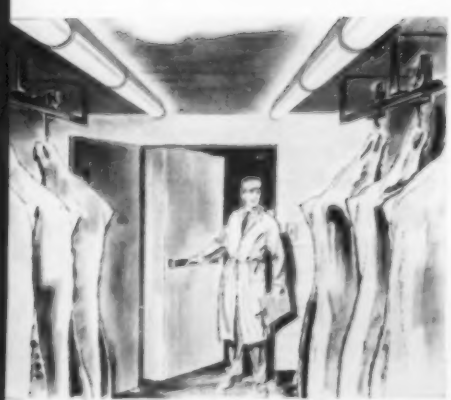

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